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ENGINEERING SOCIETY OF THE
UNIVERSITY OF NEW BRUNSWICK

CONSTITUTION .. .. and LECTURES.

1902 - 1904.

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Wm. M. Clark, Printer, Fredericton.

Officers

Of the Engineering Society

FROM THE TIME OF ITS FORMATION.

[illegible]

Hon. President, Hon. J. B. Snowball.
President, H. S. Devlin.
Vice-President, A. T. Wilson.
Sec.-Treasurer, G. E. Howie.
Rec. Secretary, A. R. Crooksha

1902 - 1903.

Hon. President, Hon. J. B. Snowball.
President, A. T. Wilson.
Vice-President, K. R. Chestnut.
Sec.-Treasurer, C. McN. Steeves.
Rec. Secretary, E. S. Dibbiee.

1903 - 1904.

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President, A. K. Grimmer.
Vice-President, G. B. Whitehead.
Sec.-Treasurer, C. McN. Steeves.
Rec. Secretary, G. H. Burnett.

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Officers of Society.

1904-1905.

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President, Moses Burpee, C E.
1st Vice Pres., G. B. Whitehead.
2nd Vice Pres., W. E. Trites.
Treasurer, C. P. Wright.
Secretary, K. A. Dunphy.

Members

Of Society, exclusive of Students.

Balkam, H. McL., Chief Engineer, N. B. C & R., Chipman.
Barbour, F. A., C. E.
Barker, R. S.
Brown, Gilmore, C. E.
Burpee, Moses, Chief Engineer B. & A. R., Houlton.
Burpee, T. C., Assistant Engineer I. C. R., Moncton.
Brydone-Jack, E. E., C. E., Prof. Engineering, U. N. B.
Bush, H. D., Chief Engineer Baltimore Bridge Co.

Devlin, H. S., B. Sc., B. A. I.
Dibblee, C. F. K.
Dixon, Stephen M., M. A.
Dunn, A. F.

Eastman, H. M., B. A. I.

Fradsham, Wm. F. B., B. A. I
Freeze, R. St. John, B. A.

Harrison, Thos., LL. D., Chancellor U. N. B.
Harrison, Wm., M. A. I., Asst. Eng. Public Works Dept, Fredericton.
Hanson, A. E., D. L. S.
Holt, F. W., C. E.

Jardine, Hugh.

La Billois, Hon. C. H.
Legere, J. A., B. A. I.

Lenihan, J. S., B. A. I.
Logie, T. G.

MacKenzie, Wm. B., Chief Engineer I. C. R., Moncton.
McLellan, R. W.
Miles, C. LeB.
McVey, A. C.
Murdock, Wm.
McMannus, J. W., B. A. I.,

Peters, Hurd, City Engineer, St. John, N. B.

Ruel, J. A.

Selig, A. C.
Shirley, E. R., B. A.
Smith, Percy H.
Stevenson, Harry
Scammell, J. K., C. E.
Scott, A. M., Ph. D., Prof. Electrical Eng., U. N. B.

Thomas, J. H., B. A. I.
Tabor, D. C.

Wetmore, A. R., C. E., Eng. Public Works Dept., Fredericton.
Wilson, A. T., B. A. I.

CONSTITUTION

OF THE

Engineering Society

OF THE

UNIVERSITY OF NEW BRUNSWICK.

(Adopted January 16th, 1904).

ARTICLE I.

NAME AND OBJECT.

Sec. 1.—The name of the Society shall be: The Engineering Society of the University of New Brunswick.

Sec. 2.—The objects of the Society shall be:

(*a*) The advancement of the knowledge of Engineering Science in the Maritime Provinces.

(*b*) The conducting of experimental and research work and the investigation of engineering materials and supplies in the Provinces.

(*c*) The promotion of increased interest [illegible] Engineering Science among the undergraduates of the University of New Brunswick

(*d*) The cultivation of a high standard of engineering and surveying work among engineers, surveyors and engineering students.

(*e*) The forming of a bond of union between graduates, undergraduates, engineers and surveyors living in the Maritime Provinces.

ARTICLE II.

MEMBERSHIP.

Sec. 1.—The corporate or voting members shall be designated as follows:—

(*a*) Senior Members.

(*b*) Junior Members.

(*c*) Student Members.

Sec. 2.—There shall also be connected with the society, Honorary Members, Associates and Fellows.

ARTICLE III.

ADMISSION TO MEMBERSHIP.

Sec. 1.—Senior Members must have had at least five years experience in their profession, or must have been engaged for five years as professors in the teaching of engineering subjects at an Engineering School of recognized standing, and who, in the opinion of the Board of Management, are qualified as such.

A diploma from an Engineering School of recognized standing will be considered as equivalent to two years practical work.

Sec. 2.—Junior members must have graduated from an Engineering School of recognized standing, or have had two years practical work.

Sec. 3.—Student members must be students of the University of New Brunswick.

Sec. 4.—Honorary Members must be of acknowledged eminence in some branch of engineering or must have had charge as head of engineering enterprises or works.

Sec. 5.—Fellows shall be those who have contributed to the objects of Society by delivering lectures, or by assisting in investigations,or by contributing to the Society, and who do not wish to become active members.

Sec. 6.—Associates shall be those who have been interested in or connected with engineering works, and who are able to aid the Society in its investigations of engineering work, materials, or supplies.

Sec. 7.—Student Members shall become Junior members upon their graduation from the University of New Brunswick, and for transition from Junior to Senior Membership, application must be made to the Board of Management.

ARTICLE IV.

ELECTION OF MEMBERS.

Sec. 1. The names of all candidates as Senior, Junior, or Honorary Members, Fellows, or Associates shall be sent to the Secretary, at least two weeks before a meeting of the Society.

Sec. 2. The names of all candidates must be approved by the Board of Management before they are submitted for election.

Sec. 3. The names of all candidates approved by the Board of Management shall be submitted by the Secretary for election at the first regular meeting after said approval.

Sec. 4. For election as Senior, Junior, or Honorary Members, Fellows, or Associates a two-thirds vote of those present at the meeting will be required.

Sec. 5. All members who are two years in arrears of fees will be dropped from membership unless they pay all back fees within two months after receiving notice that their names may be dropped in accordance with this section.

ARTICLE V.

OFFICERS AND BOARD OF MANAGEMENT.

Sec. 1. The officers of this Society shall be as follows:

Honorary President,
President,
First Vice-President,
Second Vice-President,
Secretary,
Recording Secretary,
Treasurer,
Assistant Treasurer.

Sec. 2.—There shall be a Board of Management consisting of the President, the First and Second Vice-Presidents, the Secretary, the Recording Secretary, the Treasurer, the Professors of Engineering at the University, one Senior and one Junior Member of the Society, the Dean of the Engineering Faculty being chairman.

Sec. 3.—There shall be two Auditors elected at the regular meeting in October.

ARTICLE VI.

DUTIES OF OFFICERS AND TERMS OF OFFICE.

Sec. 1.—The position of Honorary President shall be purely honorary, and he shall preside, when present, only at lectures and discussions arising therefrom.

Sec. 2.—The President shall preside at all business meetings, and, in the absence of the Honorary President, at lectures and discussions. The President shall be a Senior Member.

Sec. 3.—The First Vice-President shall perform the duties of the President in his absence. He shall be a Student Member of the Senior undergraduate class.

Sec. 4—The Second Vice-President shall perform the duties of the President in the absence of both the President and the First Vice-President. He shall be a Student Member of the Junior undergraduate class.

Sec. 5.—The Secretary shall keep a complete list of all members, send out all notices of meetings and elections, and send out ballots when required. He shall have charge of all publications, and will be assisted in his duties by the Recording Secretary. He shall be a Student Member of the Sophomore class.

Sec. 6—The Recording Secretary shall take minutes of all meetings of the Society and Board of Management, with a list of those in attendance. He shall be a Student Member of the Freshman class, elected at the regular October meeting.

Sec. 7.—The Treasurer shall attend to the collection of all fees sending out notices for same, etc,, and attend to the payment of all bills when authorized by the Board of Management. He shall prepare and submit to the Auditors some time before the annual meeting in April a statement of receipts and expenditures. He shall be a Student Member of the Junior or the Sophomore classes.

Sec. 8.—The Assistant Treasurer shall aid the Treasurer in the performance of the duties of that office. He shall be a Student Member of the Freshman class, elected at the regular October meeting.

Sec. 9.—The Board of Management shall pass upon all candidates for membership in, or for connection with the Society, and determine the status of each member and shall arrange for any regular or special meeting and arrange all business for same, and make arrangements for lectures and publications.

The Board of Management shall pass upon and authorize payment of all bills, and in general attend to all business of the Society.

Sec. 10.—The Auditors shall audit all accounts and report at the meeting in April.

Sec. 11.—All officers shall continue in office until their successors are elected.

ARTICLE VII.

NOMINATION AND ELECTION OF OFFICERS.

Sec. 1.—All officers shall be elected at a meeting to be called by the President or either of the Vice-Presidents at such a date in April as may be convenient, notice of the date of meeting being given two weeks in advance. (This section shall not apply to the offices of Recording Secretary and Assistant Treasurer.)

Sec. 2.—All officers shall be elected by a plurality of votes cast.

Sec. 3.—All officers except the President shall be nominated at the meeting held for election of Officers. Election by ballot shall succeed nomination.

Sec. 4.—A motion that nominations close will not be in order until after the expiration of one minute from the time of the last nomination.

Sec. 5.—The President, who may be any Senior Member, shall be elected by a plurality vote, the votes being cast either by letter ballot or by ballot of those present at the meeting.

Letter ballots must contain the name of the voter as well as the name of the person voted for. These ballots will be on a special form furnished by the Society.

ARTICLE VIII.

MEETINGS.

Sec. 1.—Regular meetings shall be held in the Museum of the Engineering Building or in the Library of the Arts Building at the University, on the evening of the third Friday of October, November, January, February, March and April, or on such date in the months as may be deemed convenient by the Board of Management.

Sec. 2.—Three days notice being given, special meetings shall be called by the President or one of the Vice-Presidents at the written request of five (5) members.

Sec. 3.—One third of the student membership shall constitute a quorum.

Sec. 4.—The order of business at the meetings shall be :

(1) Reading of Minutes.
(2) Correspondence.
(3) Reports of Committees.
(4) Unfinished Business.
(5) New Business.
(6) Election of Members.
(7) Notices of Motion.
(8) Lecture and Discussion.

ARTICLE IX.

AMENDMENT AND NEW RULES.

Sec. 1.—All new rules and amendments to those at present in force, shall require a two-thirds vote of those present at a meeting in order to become laws of the Society.

Sec. 2.—When any change in constitution, amendment, or new law is to be made, notice of the same must be posted at least one week before the meeting at which the same shall be voted upon.

ARTICLE X.

FEES.

Sec. 1.—The Fees for Senior, Junior and Student Members shall be $1.00 per year, payable at or before the regular January meeting.

Sec. 2.— No fees will be charged to Honorary Members, Fellows, or Associates.

Sec. 3.—A remission of fees for one year will be granted to all members who delivered lectures before the Society during that year.

Sec. 4. Members who by reason of distance from the place of meeting are unable to attend any of the meetings for one year will be entitled to a remission of 50 cents in the fee for that year.

Sec. 5.—All fees shall be payable in advance.

Notes on Railway Work.

LECTURE BY

Wm. B. McKenzie, Chief Engineer Inter-Colonial Ry.

OCTOBER 17TH, 1902.

RAILROAD work generally begins with an examination of the country through which it is desired that the line shall pass. This is called a "Reconnaissance," and may be considered an art rather than a science.

The best procurable map of the country, an axe, a pair of steel climbers, a pocket barometer, field glass, and a 7-inch Abney double-tube hand level, having vertical arc compass and telescope combined, are the only instruments really needed. Good work may be done without any of them, but they are a convenience. The catalogue prices of several very useful pocket instruments for reconnaissance are:—

Pocket barometer	$27.00
Field glass	35.00
Abney's double tube 7-inch hand level with vertical arc compass and telescope combined	17.00
Brunton pocket transit	25.00
Pocket magnifying glass	0.55

A guide should be employed, and the man who thinks he knows the whole country and every tree in it is, no doubt, the best man to have, but you must be careful to prove the correctness of his knowledge by your own work and take nothing for granted. If he is a farmer he will lead you along the highways, and if a hunter, he will lead you along the ridges.

I once came near making a very serious error in location by depending too much on a guide who "knew it all." After the completion of the survey, I had a feeling that to make assurance doubly sure, I should take two or three days to go crosswise over the country, and thus confirm the route selected beyond question or the possibility of a doubt. By the evening of the first day, I had proved that in one place the line was a mile out of the proper position;

three miles of new survey was made and the line built on it. That was a bit of experience which I shall not soon forget. . felt very thankful but the guide was correspondingly cast down.

It will be necessary for the engineer to explore the country for several miles on each side of a direct line on the map connecting the terminal points; because, no matter whether he is on the right track or not, every farmer he meets will tell him that the line should be somewhere else two or three miles away, and he must be able to tell them that he has been there already and knows more about the ground than they do The general route can be selected by reconnaissance and without the use of a transit or level, and the man who possesses the greatest skill in estimating distances, heights and grades by the eye alone, will do the best work and will do it more rapidly. This is where the "born locator" having an "eye for the country" will shine.

Reconnaissance work requires a higher order of mind than is called for in merely running in or locating the line on the ground in detail by the use of the transit and level, or in constructing it afterwards. The whole question of operating economy depends upon the reconnaissance, and no excellence of construction can correct mistakes in it. Only men of proven ability in reconnaissance sheuld be allowed to undertake this most difficult part of Railroad work—the part which irrevocably fixes the character of the road.

All the railways of the country are now suffering more or less from insufficient reconnaissance, work having been done before their final location, and this very serious error should not be repeated in future Railway work in Canada. Not a location stake should be set until the reconnaissance is completed, and in difficult country, a day to one or two miles will be time well spent.

In future, the reconnaissance man will be the important man, and it will be necessary to seek him with a lighted candle and pay him well when found. He will be a man of tact and judgement—one in a hundred—a man who loves the woods, knows some of its secrets and feels as much at home in the forest as in his own house, if he happens to have one. No matter how difficult the country may appear, always assume that there exists a good line between the two terminal points and that it is your business to find it. Do not allow the mind to become prepossessed in favor of a particular line until you have exhausted all the possibilities. Do not adopt too high a maxium gradient because it is the ruling grade which governs the cost of operation, and low grades are the most important of all the details.

When a valley rules the location literally, the problem is simple; but when the line runs across the drainage of the country, it is complex. A preliminary reconnaissance should first be made by driving over the country from one terminal point to the other, in a carriage or on horse-back, or on foot when there are no roads, to ascertain the general features, returning again to the starting point. Next, the controlling points should be noted on the map, and examined by walking over them in both directions; and it must be ascertained and decided in a general way whether they can be overcome within the limits of grade and curvature. Of course, the lowest point on ridges will be selected, and the highest stream crossings, where the grade must be continuous between the stream and the summit.

When a stream flows east or west the smoothest ground is generally found on the north side, and when the stream flows north or south, the smoothest ground is generally found on the west side. The grade of all streams increases toward the source. It is absolutely necessary to know where the water of every stream goes to. In examining the ground from tall trees or from hill-tops in rolling country, a person is liable to form entirely wrong impressions and imagine the ground to be much more easy than it really is.

A rolling irregular country having pieces of hills and valleys scattered about promiscuously and trending in different directions, is the most aggravating kind of a country to the locating Engineer, and he requires a great deal of hard work before he can be assured that he has secured the best line; almost any person can locate along a shore or river valley. Except, perhaps, at summits do not let the existance of a highway have any influence on your location. The pocket barometer is a very useful instrument, but like the guide, it is very apt to lead you astray, and requires careful watching.

Things are not always what they seem, and you must be continually on your guard against what is termined "Ocular illusions" —for instance:—a slope observed in front with the sky as a back ground always appears higher and steeper than it really is. Looking against a mountain, you will imagine the ground falling towards the mountain when it is really rising, and a stream flowing towards you will appear to be runing up hill. If, at the foot of a mountain, there is a small hill with a valley the same height on each side of it, the valley next the mountain will appear to be the lowest. Hills overlapping at a distance will give the appearance of a solid ridge. Many errors have been made from this cause. Hills are deeper than they seem to the eye looking directly down on them. When a slope is observed from the top, it appears to be steeper than it really is. Longitudinal distance appear shorter than they really are when looked at across water or low land. Lateral distances are exaggerated and appear longer than they really are. In clear air, judging distances is almost impossible without comparion to some known distance, but practice will show at what distance known objects, such as the outline and style of a man's hat, becomes visible. The distance to a rock observed across an unseen valley is almost impossible to estimate. In a hazy atmosphere, the amount of haze between you and the object is some guide to the distance. When looking towards the setting sun, the distances are less than they appear to be. Weights and distance are more easily judged on days when the sun is obscured. Distances can often be taken with sufficient accuracy by observing the time occupied by the passage of the report of a gun from one point to the other. This may be done in the day time if there is a field-glass handy to watch for the smoke, but otherwise the flash of course can be best seen at night. The velocity V, in feet per second, with which the sound travels depends on the temperature; thus at 32 degrees F, V equals 1090 feet; at 60 degrees F, V equals 1125 feet and at 100 degrees F, V equals 1175. If the wind is blowing hard in the direction from which the sound comes, the velocity of the wind may be added to V. When the observers are not visible to each other, two guns may be used. If one fires instantly on hearing the other, repeating this three or four times, one-half the number of seconds from the firing of your gun to the reply of the other multiplied by V will give the approximate distance in feet.

Sounds travel to greater distances in cold air: they are not easily heard during a snowstorm, but they ascend readily and are more distinctly heard on the hill-tops.

If your pocket compass has been forgotten,and the sun being invisible you discover that you are "lost," a few of the secrets of the woods may be of service. You will find a compass almost anywhere by observing that the moss and fungus grow on the north side of the trees; that a lonely bare rock will show the south side dry and bare, and the north side damp, mouldy and mossy. The sunny or south side of a hill will be dry and noisy under foot, while the north side is mossy and damp; this also applies to clumps of trees, bushes big rocks, etc. The golden-rod droops to the south, and the color of the club-rush (cat-tail) is lighter on the south side. The bark of the coniferous trees is of a lighter color, harder and dryer on the south side, and is darker, damper and sometimes carries moss on the north side. The gum or balsam is clearer, cleaner, and harder on the south side, and soft, sticky and full of insects dirty and gray on the north side. Nests and webs of insects are in the crevices of the bark on the south side. Birds' nests are usually built, and woodpeckers' holes usually made on the south side of the trees. The green leaves are of a lighter color on the south side. On steep hills of mountains trees grow larger and more uniform on the north slope, next best on the east slope, while on the south and west slopes, the ground is often bare. It is well to note the direction of the wind each morning and the dip of the rocks if uniform, as this knowledge alone may help you out of the difficulty.

If the direction of the prevailing wind in that part of the country is known, an isolated and exposed tree will show it, as it will be found to lean more or less away from the prevailing wind. If it is known that a noted gale from a particular quarter once blew down large sections of the forest, look at the fallen trees. If you wish to know the age of a "blaze" on a tree, cut squarely through the wood which has grown over or partly over the "blaze" and count the annual rings from the black marks outwards. In the Eastern part of Canada quartz veins run nearly east and west, and ice markings on the rocks run southeast.

After you have succeeded in finding yourself again, some important considerations may occupy your mind such as the following:—The *difference* in gross receipts between different lines; the *difference* in operating expenses between different lines; the *difference* in interest charges between different lines. Deviations to outlying villages which may be made to secure local traffic, may extend to 1-10 the air line distance between terminals measured on either side from the air line itself. Ten per cent of the traffic originating in small towns will be lost for every mile the line is placed away from the town. Such towns, however, gradually build up towards the Railway. 25 to 50% of the traffic originating in cities where there is competition will be lost for every mile the line is placed away from the city. Stations should be as nearly as possible in the center of the cities or towns, particularly at Terminals.

For lines of heavy traffic (say 10 trains per day, round trip) if the gross revenue can be increased 1-5, the whole investment may be doubled.

If the gross revenue can be increased 1-10, the cost of track and roadbed may be doubled.

If the gross revenue can be increased 1-20, the cost of subgrade may be doubled.

Distance: For savings of three miles or less, assume that the cost of operation is 80 cents per mile for every daily train making a round trip (going and returning). Then 80 cents × 350 days in the year = $280.00 per year per daily train round trip (going and returning). If borrowed money cost 5% interest, we are entitled to spend $5,600.00 extra on the construction of a certain route, if by so doing we can save a mile of level track ; because this is the sum which at 5% interest will produce $280.00. For two trains making round trips per day (going and returning), we should spend twice as much . and so on.

Rise and Fall: Assume an operating cost of 80 cts. per mile for every daily train making a round trip (going and returning). Then on grades between 0.75 and 2.00 per 100, when hills are 40 to 50 feet high, the annual cost for operating one foot of rise and fall per daily train round trip (going and returning) may be estimated at $1.44. If borrowed money cost 5% interest, we are entitled to spend $28.80 in the reduction of one foot of rise and fall ; because this is the sum which at 5% interest will produce $1.44. For two trains making round trips per day (going and coming), we should spend twice as much ; and so on.

Curvature. Assuming an operating cost of 80 cents per mile for every daily train making a round trip (going and returning)

The annual cost of operating one angular degree of curvature per daily train round trip (going and returning), may be estimated at 28½ cents. If borrowed money costs 5% interest, we are entitled to spend $5 70 to lessen a curve by one angular degree of curvature; because this is the sum which at 5% interest will produce 28½ cents. For two trains making round trips per day (going and returning), we should spend twice as much; and so on.

Locomotive Haulage: To find the load which a locomotive can haul up a given grade at ordinary freight speed, use the following formula:

$$L = \frac{100W}{1 + 4r.} - E \qquad (1)$$

L = Load in tons of 2,000 lbs., which can be hauled behind tender.

W = Weight on the drivers in tons of 2,000 lbs.

E = Weight of locomotive and tender in tons of 2,000 lbs

r = per cent of grade.

The above is based on a rolling resistance of 5 lbs. per ton on straight level track.

Note: Deduct 20% from L in winter.

Comparison of Routes: A line is 50 miles long between terminal points and has a ruling grade of 1¼ per 100. How much additional money would we be entitled to spend to secure a 1 per 100 grade, having to carry 2,000 tons of freight in one direction every week day. By applying formula (1), it is seen that our engine will haul 1,000 tons up a 1 per 100 grade, and only 824 tons up a 1¼ per 100 grade—a difference of 176 tons per train. On the 1 per 100, therefore, we would require two trains per day, carrying 1,000 tons each; while if we used the 1¼ per 100 grade, we would have 216 tons × 2 trains × 6 days, = 2,112 tons of freight piled up at the receiving end at the close of each week.

This would require two special trains per week, = 0.33 of a daily train; and to operate these two special trains would cost annually: 0.33 of a daily train × 80 cents per mile per daily train round trip × 50 miles × 350 working days in the year = $4,620.00, and this capitalized at 5 % = $92,400, which is the additional sum that we would be entitled to spend to secure a 1 per 100 grade instead of 1¼ per 100 grade.

Now, we may accomplish this in either of two ways: either spend the $92.400.00 in cutting down the 1¼ per 100 grade to a 1 per 100 grade; or if this cannot be done, divert the line on to new ground which will afford a 1 per 100 grade, and add 3½ miles to its length. This latter proposition is proven thus:

To operate 1 train round trips over one mile additional during 1 year = 80 cts × 350 days =	$ 280
To operate 2 trains round trips over 1 mile additional during 1 year =	560
To operate 2 trains round trips over 3½ miles additional during 1 year =	1,960
Assuming construction to cost $52,500 for 3½ additional miles, at 5 % =	2,625
Annual outlay which nearly equals the $4.620 that we are entitled to spend annually to secure a 1 per 100 grade =	$4,585

Business and ruling grade should determine the general route. Most of the lines of 20 and 30 years ago were pioneer lines, and steep grades and sharp curves were freely used to lighten the cost of construction, as nothing else would have been paid for at that time. There was not then the same necessity for the extensive and thorough reconnaissance which is now imperative in this day of heavy traffic and low grades.

Far too little time was formerly given the engineer for reconnaissance work. In my own experience I once, because of an incorrect plan, ran my preliminary line into a lake, instead of passing by the end as I intended. As the work had already been advertised for tender, no time was left to make changes, and the road today runs through the middle of the lake.

Once, after completing the reconnaissance, I put on two survey parties and, while keeping ahead of the preliminary party and giving them general directions, I was able, with the aid of 20 in. × 30 in. sheets on which the preliminary work had been plotted the night before, to lay down the location at odd times in the day, using the flat wooden case in which the sheets were carried as a table. These sheets were, one by one, carried back to the locating party, and the whole combination was thus kept moving. Such work is too much for one man, and those who do it receive few thanks as a rule

Be sure that you do not use the maximum grade or curve oftener than is absolutely necessary.

When you are climbing toward a summit, try to avoid losing elevation by inserting reverse or down grades, but look well for support ing ground to right or left, and thus by gaining distance reduce the cost of grade.

If the country is such that high grades must somewhere be used, try to bunch them in one division, and reduce grades to the utmost on all the other divisions.

Reconnaissance should be so thorough that a close preliminary line can be run and sufficient topography taken within 300 or 400 feet on either side. This may be shown on plan by contour lines, or elevations in figures. From this data, a paper location plan and profile is made. When running in this paper location is the time to study the ground in detail and make necessary changes.

This general method of reconnaissance and preliminary, having the details filled in to the extent necessitated by the character of the country, should result in good location at reasonable cost.

For practical information on railroad location and construction, consult :—

"The Economic Theory of Railway Location", by Wellington, 1887.

A series of Articles by Wm. G. Raymond, in the Railroad Gazette, Nov. and Dec. 1898 ; "Rules for Railway Location and Construction", by E. H. McHenry, Chief Engineer of the Northern Pacific Railroad, now Chief Engineer of the Canadian Pacific R'y.

The latter book is the most comprehensive and complete book of instructions so far published on the subject, and it has recently been reprinted by the Engineering News Publishing Co., New York. Price, $1.00.

PRELIMINARY LINE :—The preliminary survey is usually made with transit and level and a party of 10 or 12 men, who will follow the general line shown by your map and a few marks left by you on the ground. Your place will now be one or two miles ahead of the party, exploring the ground in detail and leaving marks for the guidance of the transit-man. It would be a mistake for you to try to be transit-man and chief of party at the same time : the result would be a poor line.

The levels should be plotted up every night, and more frequently if running on a maximum grade, so as to indicate whether you should move higher up the hill or nearer the valley. The preliminary should be kept as near as possible to the final location—never more than 200 or 300 feet away from it ; and this is called a close preliminary.

A topographer is required who will take hand-level cross-sections for 200 or 300 feet in width on either side at every 100-foot station where the ground is rough, and less frequently on more favourable ground. A man of good judgment will need to use the hand-level only when the ground is decidedly rough, because he can estimate the slopes very closely. These cross-sections are needed so that when a location is laid down on the plan away from the preliminary line a profile may be constructed from the topographer's notes. The most convenient form of note-book is one having a vertical column in the centre of the page, in which the station is written , then the distance out to the right is made the numerator of a fraction, the plus rise or minus fall below the ground at the station being the denominator of the fraction: the same on the left side of the column, always working up from the bottom to the top of the page. The topography is noted on the plan for guidance in working up the paper location.

Location: From the preliminary plan, profile, topography and cross-section, a line is located on paper, and another profile prepared which shows roughly what the character of the located line will be as to grades, cuts and fills. Say that this profile proves it possible to obtain a maximum grade of 1 per 100 on a straight line. If curves occurr on this maximum grade, the grade must be reduced by 0.04 of a foot for every degree of curve: Thus, on a 5 degree curve, the grade would be reduced to 0.80 per 100. You would be justified in lengthening the line ⅛ if by doing so you could reduce the grades by 50%. That is: have a line 112.5 miles long with 0.5% grades rather than one 100 miles long with 1% grades.

We can now go into the field with our location plan and profile, and run the line in on the ground according to the paper location, making improvements as a careful study of the ground shows to be possible. The maximum curvature specified has usually been 6 degrees and the grades 1¼ to 1½ per 100, for company lines. The I. C. R. standard was 5 degree curve and 1 per 100 grades.

Construction: The preparation of contract plans, profiles and specifications is a work requiring knowledge of railway construction, which can only be acquired by actual experience in the field. For entire success, a good theoretical foundation is an absolute necessity. Much information can be gleaned from other men who have done work of a similar character, and from their plans, specifications, and writings. It is a good plan to keep a scrap book and have it well indexed, so that you can record notes even if these notes are only the name of a book or paper, where, on a certain page, you can find an article on a particular subject; perhaps the composition of the concrete used in the lock walls of the Soulanges Canal, the section of the Chaudiere dam, or a standard grading specification, &c., &c. In a few years, a large percentage of the notes will be obsolete, out of date, back numbers, but it will still be a mine of hints and suggestions.

After the work of construction has been let to the contractor, then comes the staking out on the ground: such as setting out the side ditches, putting in slope-stakes, fence-stakes, staking out and making plans of special culverts and bridge foundations to suit particular cases. No matter how many standard typical drawings there may be, a working drawing should be made for each structure after cross-sections have been made and the nature of the bottom ascertained, preferably by sinking a test pit. This brings us to the subject of foundations, than which none other is of more importance. Some one has said "It is the foundation of the foundation that you must look to," and the older one grows the more importance he seems to attach to the question of the "Foundation of the foundation," for, without a proper foundation, the most magnificent superstructure will go to pieces as did the Campanile recently. No subject requires greater judgment, more actual every-day experience and more common sense than this of foundations. Scarcely two should be treated precisely alike.

The matter of testing the bottom by driving down an iron bar, by boring with a percussion drill, or by driving test piles is of very great importance; but I regret to say that it is very often omitted because of the time and expense connected therewith. A reasonable sum of money should always be expended in ascertaining the character of the bottom under any structure of importance, Mistakes are sure to be made if this is neglected, and mistakes are sometimes made when it is not neglected, because of the lack of judgment on the part of those making the tests. I will give you two or three instances:—

I once sent a man to take soundings and test the bottom with an iron bar, where a $100,000.00 creosoted pile wharf was to be built.

The water was from 20 to 40 feet deep, and the bar sprung so much that it could not be forced into the bottom for any great distance, and hard material was reported as lying within 4 or 5 feet of the surface. This seemed to be confirmed by piles driven in an existing wharf a few hundred feet away. Creosoted piles were ordered at about 40 cents per lineal foot, allowing what was considered a liberal margin in length for cutting off at the upper end ; but when work began about one half of the whole lot were found to be too short, the hard material being further down than was expected or indicated by the tests with the iron bar.

Three or four test piles would have prevented this error, but no pile driver or scow was at hand ; or perhaps better judgment in the use of the bar might have prevented it. In this case the piles were not all creosoted when the error was discovered, and it was possible to obtain longer ones for the same price per foot. Those already delivered were spliced, some at the upper end, with a splice after they were driven. See plate 1, Fig. 1 ; and some spliced at the lower end by a splice before they were driven. See plate 1, Fig 2.

These splices cost about $3.50 each, and were an addition to the cost of the work. In another place, wishing to profit by past experience, I hired a pile-driving outfit and drove 9 test piles for a new creosoted pile wharf. The foreman drove these test piles so hard that they were split and bent up at the point ; and the result was that the creosoted piles for the wharf were ordered too long, and pieces from 3 feet to 10 feet long had to be cut off. These piles cost 42 cents per lineal foot. Borings made with a percussion drill sometimes give an erroneous idea of the bottom ; because the material which comes through the sand-pump has been reduced to powder and mixed with water, so that it is almost impossible to distinguish sand from sandstone rock, and only a driller of experience can judge from the feel of the drill the kind of material it is passing through. When on ledge rock, it is usually possible to feel a slight bouncing on dropping the drill-rod. I once sent an experienced driller to bore a hole on the site of a high chimney. He reported that the bottom would require to be piled ; but on excavating 6 feet below the surface, the hard-pan was considered amply sufficient to bear the weight of the chimney, the foundation being spread so that the pressure was reduced to 1½ tons per square foot

PLATE I

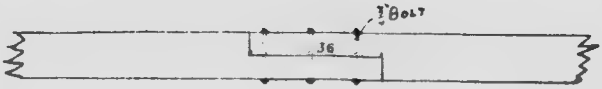

FIGURE 1

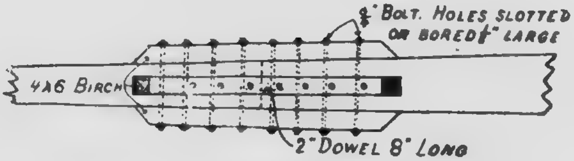

FIGURE 2

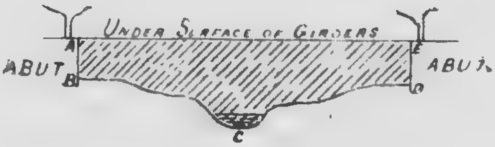

FIGURE 3

when a 40 mile per hour wind was blowing against the chimney. For shallow borings in earth, take a locomotive boiler flue. Make slot holes ¾ in. × 6 in. in a spiral winding around the flue. Sharpen one end. Insert a heavy solid screw cap 3 in. long. Drive with a heavy sledge. Turn pipe with large chain tongs. Lift out with a lever. A boring made with a 2½ in. casing pipe, ⅞ in. hollow rod and 2 in. bit will cost 54 cents per lineal foot. See "Engineering News", June 28, 1900.

It seems easier to make mistakes in foundation work than in most other things, and here particularly we should try to remember that "Error is the rule, truth the exception."

LOADS ON FOUNDATION BEDS: If the natural soil is considered sufficiently firm to carry the structure directly, be sure that you do not overload it. The following loads will be safe :—

On loam or marshy soil—½ ton per sq. ft. ; failure has occurred under one ton per square foot.

On stiff clay—1½ tons per sq. ft. ; failures have occurred at 2 tons per square foot.

The Washington monument failed at 5 tons per square foot. On soft marsh, I would not go over ½ ton per square foot. To get sufficient bearing area, it will sometimes be necessary to step out the foundation courses to an angle of 45 degrees.

On sand—3 tons per sq. ft. ; failures have occurred at 4 tons per square foot.

On gravel—4 tons per square foot ; failure has occurred at 8 tons per square foot.

On rock—5 tons to 25 tons per square foot, according to the quality of the rock.

If you have a soft material overlying a hard stratum, piles are called for, provided they will always remain saturated with water. If not, they will decay in a short time, and some other character of foundation should be adopted. Suppose that you do use piles ; then you will first consider what total weight there is to be carried on the piles. For the sustaining power in pounds of a pile with a factor of safety of six, use the Engineering News formula :

$$\frac{2\,wh}{s+1}$$

w = weight of hammer in pounds.
h = height of fall in feet.
s = penetration under last blow of hammer in inches.
1 = a constant.

For instance: say your hammer weighs 2,000 lbs., the fall is 20 feet, and the penetration under the last blow is 2 inches, then:

$$\left.\frac{2\times 2000\times 20}{2+1}\right\} = 26{,}666 \text{ lbs.},$$

for the sustaining power of the pile with a factor of safety of 6. In important work, I would not use a greater load than 10 tons on any pile, and I have sometimes brought this down to 8 or 9 tons. A good general specification for pile driving is the following:—

"Piles shall be driven to such depths that the last blow of a 2,000 lb. hammer freely falling 20 feet shall not produce a greater "penetration than one inch, or an equivalent penetration directly "proportional to the weight of the hammer." This is termed "Driving to a *refusal*." The fall should then be reduced to 6 feet and the driving stopped at $\frac{1}{4}$ penetration. No penetration less than one inch should be used in the formula

$$\frac{2\,wh}{s+1}$$

which would in this case give 20 tons as the safe sustaining power of the pile; the factor of safety being 6.

Foundations: In some soils, such as the boulder clay at St John, piles may be placed on top of each other and still continue to go one or two feet at a blow for 50 or 100 feet down; but if the driving be stopped and the pile allowed to stand over night until the clay has settled around it, several blows will be required to start it next morning. In such cases, I specify that the third blow next morning shall be the penetration used in the formula

$$\frac{2\,wh}{s+1}$$

for the sustaining power of the pile.

The proper sizes of piles are as follows: (See Eng. News Sept. 21st, '99).

	DIAM. LARGE END.	DIAM. SMALL END.
Up to 30 feet	12 to 16 in	10 in.
Up to 40 feet	" "	9 "
Up to 50 feet	" "	8 "
Up to 60 feet	" "	7 "
Up to 70 feet	" "	7 "
Up to 80 feet	" "	7 "

Spruce piles driven into different soils with a 1,200 lb. hammer falling 15 feet would safely sustain the following loads:

Kind of Material	Pile Length in ft.	Average diam inches	Penetration inches	*Safe Load, tons
In silt	40	10	6	2¼
Mud	30	8	2	6
Soft earth with boulders or logs	30	8	1½	7
Moderately firm earth or clay with boulders or logs.	30	8	1	9
Soft earth or clay	30	10	1	9
Quicksand	30	8	⅓	12
Firm earth	30	8	½	12
Firm earth into sand or gravel	20	8	¼	14
Firm earth to rock	20	8	0	20
Sand	20	8	0	20
Gravel	15	8	0	20

*For important works I would not use over 10 tons per pile.

On the piles under the pedestals of the Boston Elevated Railway, the pressure has been limited to 10 ten tons per pile. Under the Hillsborough bridge piers on P. E. I., I have limited the pressure to 9 tons per pile.

PILE FOUNDATIONS:—Next to hard wood, spruce will stand harder driving than any other wood in this country. Piles should have the bark removed before driving, because there is a danger of water loosening the bark, when the pile will sink in the bark and destroy the structure. In places where the piles cannot always be kept wet, they should not be used: and if the soil is not sufficiently firm, it must be compacted by other means, such as sand piling, or by removal of the material by dredging inside of bottomless caissons, or by means of pneumatic caissons Many of the bridge abutments of our railways, which are supported on piles have been pushed forward by the pressure of the earth embankments and this will usually happen where the bottom is soft, because the whole bank settles, and the lateral pressure causes the clusters of piles to spring forward bodily. This may be prevented by driving spur piles in front, or by depositing heavy rip-rap, or by land ties back into the bank. Under piers in soft bottom, piles make a very good foundation when the piers are well rip-rapped with stone, because there is no side pressure. In driving piles in soft bottom, begin at the outside and work inwards, so as to consolidate the ground. When the ground is hard, begin at the centre and work outward. Sharpen piles to a 4 in. by 4 in. square point for hard driving and use cast iron bonnets on the piles. Pile-shoes as ordinarily made are of no use. The only proper shoe is of cast iron, cone-shaped, and not less than 8 in. diameter inside the rim, with a 1½ dowel Where it is necessary to cut off piles under water, it is usually done with a horizontal circular saw on a vertical shaft, the driving engine being placed on a scow, or on a frame-work erected for the purpose, but when the piles are being driven through soft material like sand or stiff clay, the heads may be protected by a metal hood and the piles driven with a dolly or follower to an exact grade This is done by first driving a test pile and gauging the proper lengths of the others each by the last one driven. Perhaps in driving 100 or 200 piles, five or six may be too long; but a diver can be sent down to cut these off. This method will be much cheaper than cutting them all off with a saw. Grade is given by a levelling instrument set up on shore. In a large work now doing in Canada, hundreds of piles have been driven to exact grade in this way in water 50 feet deep.

In places where piles are not desirable, the ground may be consolidated in the following manner: Prepare a piece of hard wood 4 in. diameter 6 feet long, pointed at one end, and having an iron ring on the other end. Drive this down about five feet with a hand maul, pull it out again with a lever and chain, pour sand or gravel into the hole and pack it down with an iron bar. Begin at the outside and work towards the centre, putting the holes about 18 inches apart. By the time you reach the centre, the ground will be almost as hard as rock. I have used this very successfully under bridge abutments and turn-table centres. In Paris, the ground under the Exhibition Buildings was consolidated in this manner, though on a larger scale. There, a cone-shaped casting or punch was used which weighed 2,000 lbs. This was exactly like the hammer of a pile-driver, being allowed to fall from the top of a pair of leaders about 20 feet high. The punch, on falling, buried itself in the soft ground, and was pulled out by the wire rope attached to the drum of the engine. Sand or gravel was then shovelled into the hole and the punch allowed to fall again into the same hole; and so on until the hole was filled. The leaders were then moved 4 or 5 feet away, and the same thing repeated until the whole area was consolidated in some cases to a depth of fifteen feet below the surface. Two shapes of punches were used. A testing hammer, was also first used to test the carrying capacity of the natural ground, so that the degree of additional consolidation required might be estimated.

A common method of placing a masonry pier on a pile foundation in deep water is to build the pier inside of a watertight caisson or box until the weight of the masonry sinks the box on to the heads of the piles. This was done at the Grand Narrows bridge, Cape Breton, in 70 feet of water. At this depth, the pressure was 30 lbs. to the square inch, or over 2 tons to the square foot; so that thorough caulking and inside bracing was required to prevent collapse of the caisson from the water pressure. Another method is to sink a bottomless caisson, and then dredge inside until the box sinks to hard bottom, when concrete is deposited in the water through a chute until a thickness of concrete equal to about one-third the depth of water has been put in; then pump out the box and lay the masonry in the dry. The deepest foundations of this kind in the world are those of the Hawkesbury bridge, in Australia, where great trouble was caused by overloading the caissons with concrete, and forcing them into the mud. The result was, that, following the line of least resistance, two of the caissons landed several feet out of line. Dredging or excavating should be done at or below the cutting edge, and no more weight used than is barely sufficient to overcome the friction of the material against the sides, until the cutting edge has reached its final position; this applies also to pneumatic caissons

Next comes the pneumatic caisson, where men work in compressed air down to a depth of 90 or 100 feet below the water level. At these depths, men can only work about $\frac{3}{4}$ of an hour out of the 24;

and this ¾ of an hour's work ms $8.00 or $10.00.

Pneumatic Caisson Work : A short time ago, I was down in the working chamber of the Quebec bridge caisson. The depth of the water was about 37 feet, and the pressure about 15 lbs. per square inch. The bottom was large boulders, gravel and sand. Drilling of boulders was going on at several places under the cutting edge in about two feet of water. The centre was several feet lower than the sides. Under each of the two shafts, 2 men were standing, one holding a water-jet of 100 lbs. per square inch against the gravel bank, while the other held the flexible end of a 4 in. blow-out pipe through which sand and gravel was forced out by the compressed air over the top of the caisson. Stones 2 or 3 inches in diameter went out through the pipe, and about 30% of the whole excavation went out by these two discharge pipes, the remainder being hoisted out in buckets through the shafts. Men were stripped to the waist and the place was a busy one. The shifts were :

$$\left.\begin{array}{r}3\frac{3}{4}\text{ hours in caisson}\\ \frac{1}{2}\text{ hour up at lunch}\\ 3\frac{3}{4}\text{ hours in caisson}\end{array}\right\}\text{ 1 shift in 24 hours.}$$

Pay at that time was $3.00 per day of 24 hours.

Pneumatic Caisson Work at Hillsborough Bridge, P. E. I., Season of 1902 : The pressure was 32 lbs. per sq. in. on pier No. 9. Two shifts of 2 hours each in 24. Interval between shifts, 4 hours. Wages for "sand-hogs," $3.25 per 24 hours. 50 "sand-hogs" on the work. Temperature, 83 degrees Fah. in the working chamber. 2 schooners were carrying 680 tons each of stone per trip from Wallace, N. S.

Structures of Timber ; The pitch pine timber usually imported into this country is the long leaf pine (Pinus Sylvestris), and it is nearly all tapped timber ; but this in no way affects its strength or durability, the liquid resin being confined entirely to the sap wood, which in sawing is nearly all removed except one or two inches on the corners. Long-leaf or hard pine will last 18 to 20 years, exposed to the weather. Timber after being framed into a structure, such as a bridge, and exposed to the weather, increases in strength for a few years and then decreases rapidly. White pine will increase in strength 20% by the end of the third year, and should be renewed the tenth year. Red pine will increase 5% in strength by the end of the 4th year, and should be renewed the 8th or 9th year. Wood bridges on the I. C. R., having hard pine chords, white pine webs and floors, lasted 14 to 22 years—average 18½ years. Wooden bridges on the P. E. I. Railway of white pine lasted 22 years. Wooden bridges on the Canada Eastern are now in use 17 years, floors and certain other parts having been once renewed. The chords are of hard pine.

The life of timber bridges on the Boston and Maine Railway is:

	STRINGERS, YEARS.	TRESTLES, YEARS.	TRUSSES, YEARS.
Long leaf Southern pine	12 to 14	15 to 20	15 to 20
White pine	10 to 12 yrs.		14 to 17
Spruce	6 to 7		8 to 10

(See Eng. News, Oct. 26th 1899).

Wood is composed of: carbon, 52.4 parts, hydrogen, 5.7; and oxygen, 41.9, and the specific gravity of Southern pine is .64 to .80. The bark forms 10% to 15% of the volume. The annual rings are closer together at the top of the tree, and logs cut from the foot of the tree are 7% stronger and two pounds per cubic foot heavier. The greater the weight, the greater the strength. The strongest wood is one-third the distance from the heart, and the strength decreases from the heart to the periphery 15% to 25%. Large beams are from 10% to 40% weaker than small beams of the same material. Green beams fail first on the compression side. Seasoned wood is 50% to 100% stronger than green wood. Wood seasoned out of doors under shelter retains about 15% of moisture. Wood used indoors retains about 10% of its moisture. The heaviest wood shrinks most in drying. Top logs shrink 15% to 20% less than butt logs. It is only owing to the looseness of texture that most timbers are lighter than water. Immersion in fresh water soon after felling makes timber more durable, and one year in salt water doubles the life of timber. The time of felling has no effect on the strength of pines.

Green sap wood contains about 50% water: it is heavier than heart wood, and the part formed in the summer is twice as heavy as that formed in the spring. Sap wood contains 1% to 4% of resin, and about $\frac{1}{6}$ of the resin is composed of turpentine. It is from the sap-wood of the long-leaf pine only that resin is obtained by tapping. Sap-wood shrinks one quarter more than heart wood. In trees 25 years old, sap wood changes to heart wood in 30 to 60 years. In trees between the ages of 80 and 100 years, the sap wood is the strongest, and in the short leaf pines forms about 60 of the volume. Unseasoned heart wood contains about 20% water, and contains 5 to 24 of resin, about ⅙ of which is composed of turpentine. The resin is thick and will not flow when the tree is tapped, the cells of the heart wood being dead and containing only air or water. At the top of the tree, the heart wood is the strongest, the annual rings being there closer together.

STRESSES IN TIMBER. – The safe allowable stresses for use in railway work are, for transverse rupture, with factor of safety of 6 :

White Pine	700	lbs. per sq. in.
Red Pine	800	"
Spruce	700	"
Hemlock	600	"
Hard Pine	1,200	"

And the strength of beams may be ascertained thus :

$$M = \frac{1}{6} fbh^2$$

M = Max. bending moment in inch-pounds

f = Allowable stress per sq. inch in outer fibre.

b = Breadth in inches.

h = Height in inches.

STRUCTURES OF CONCRETE : The best and most concise specification I know for mixing concrete is the following :—

One measure of sand shall be evenly distributed on a timber platform, and one measure of cement shall be distributed on the sand, and a second measure of sand shall be thoroughly mixed in a dry state, being turned over with shovels until this is accomplished. Water shall then be added through a sprinkler in sufficient quantity to convert the sand and cement into a mortar which will stand in a pile and not be fluid enough to flow. During the applicetion of the water, the mass must be constantly turned with shovels, so that the mortar will be of uniform consistency. The broken stones shall first be immersed in water, and then spread evenly on the mortar to be a depth of about 8 inches ; and then begin the turning with shovels. Turn not less than four times, exercising care not to heap the masss, but simply turn it over, keeping the original thickness.

Each piece of broken stone must be coated with a homogeneous film of mortar. A four tined fork made from in. steel shall be used to prevent the stones from touching the moulds.

Concrete must be mixed in small and convenient quantities, and immediately deposited in the work before the initial set begins.

Gravel will make a denser concrete than broken stone. The sand and gravel is of as much importance as the cement. Stone masons, as a rule, know nothing about making concrete, and, because they think they know it all, are more difficult to teach than an ordinary labourer. One good man and a few common labourers is all that is needed for the best concrete work, and this is why it is generally cheaper than stone.

Concrete weaker than cememt, one part—sand, two parts—broken stone, 4 parts, should not be used for railway work; but 20% of stone displacers may be used where walls are sufficiently thick, provided the stones do not touch each other or come nearer the face than 2 or 3 inches.

Put in expansion joints about every 30 to 50 feet by putting up a board in the mould with tarred paper behind it. Place the concrete against the paper, and remove the board after the concrete has set.

Hard stone is better than soft stone in concrete, for the reason that it absorbs less water than soft stone.

Magnesian limestone absorbs 1-4 its bulk of water.

Oolite absorbs 1-5

Compact sandstone absorbs 1-8.

Hard granite absorbs 1-40.

The broken stone must be soaked with water and the moulds must be kept wet also, so that the water may not be absorbed from the cement before the concrete has set. Cover the concrete from the sun and wind. A stone mason will get his moulds off as soon as possible, so that the concrete may "dry out", as he terms it; but this is an error; the water does not evaporate, but combines chemically with the cement.

The cost of good concrete in Canada is from $6.00 to $10.00 per cubic yard, according to where the sand and gravel come from and the time of year in which the work is done. It may be built in winter by heating the materals, but this will make it cost $10.00 to $12.00 per cubic yard.

Mixtures of $\left\{\begin{matrix}1-2\frac{1}{2}-5\\1-3-6\\1-4-8\end{matrix}\right\}$ are used in heavy walls, such as canal locks and bridge abutments.

A finer facing is put on of 1-1-0 or 1-2-0 from 1½ in to 3½ in thick, but care must be taken that it is placed at the same time as the body concrete. Any face work done with the trowel after the body has set will come off in two or three years. If you wish to render concrete water-tight, brush it with four coats of cement wash, of cement, 6 parts; sand, 1 part. Mix fluid in buckets close to the work and use immediately. If you wish to protect iron foundations from corrosion, cover the metal with 3 in. of concrete and brush on three or four coats of boiling tar.

Waterways: Diverting streams to save building culverts usually causes trouble; and the law is that if you divert a natural watercourse you must take charge of the water and pay any damage it may do between the point where the diversion begins and where it joins the original watercourse.

The proper openings may be calculated from Myers' formula, which is:—

Area of waterway in sq. ft. $= C \times \sqrt{\text{drainage area in sq. acres.}}$

For comparatively flat ground or slightly rolling prairie, C = 2

Hilly ground .... C = 3

Mountainous and rocky ground .... C = 4

The drainage area may often be approximately obtained from maps.

The openings used on the Rock Island & Pacific Railway in Kansas, Nebraska and Eastern Colorado are:—

	MIN. (acres)	MAX.
1 line of 16 in. cast iron culvert pipe	20	40
1 " 20 " do.	30	60
1 " 24 " do.	45	90
1 " 30 " do.	70	140
1 " 36 " do.	110	220
1 " 48 " do.	180	360
6 ft. Arches, 4 ft. side walls	240	400
8 " 4 " do.	320	550
10 " 5 " do.	500	850
12 " 6 " do.	720	1,300
16 " 8 " do.	1,250	2,300

Another formula is : –

$$\text{Area of waterway in sq. ft.} = \frac{\text{Drainage area in sq. acres}}{C}$$

For ordinary flat and rolling land, as found in good agricultural countries..... ....C = 6

For very mountainous country, slopes steep and abrupt........C = 4

WATERWAYS

Track opening, N. Y. Central standard:

5 acres	steep slope	....	10 in. pipe
5 “	flat land	....	10 “ “
10 “	do.	....	12 “ “
20 “	do.	....	16 “ “
25 “	do.	....	18 “ “
30 “	do.	....	20 “ “
70 “	do.	....	30 “ “
110 “	do.	....	36 “ “

Pipe culverts, minimum fall – 3 in. in 12 feet.

THICKNESS REQUIRED FOR CULVERT PIPES.

Cast Iron Culvert Pipe :

12 in.	diameter	=	$\frac{3}{4}$ in. thick
18 “	“	=	$\frac{7}{8}$ “ “
24 “	“	=	1 “ “
36 “	“	=	$1\frac{1}{4}$ “ “
48 “	“	=	$1\frac{1}{2}$ “ “

Concrete Culvert Pipes :

Under 30 in	diameter		3 in.
30 in.	diameter	=	4 “
36 “	“	=	8 “ thickness of wall
42 “	“	=	8 “ “
48 “	“	=	8 “ “
84 “	“	=	12 “ “
60 “	“	=	12 “ “

Earthenware Double-Strength Culvert Pipe :

12 in.	=	$1\frac{1}{2}$ in. thick,	30 cts. per foot
15 “	=	$1\frac{3}{4}$ “ “	45 “ “
18 “	=	2 “ “	60 “ “
24 “	=	$2\frac{1}{2}$ “ “	1 40 “ “

It is not good practice to lay earthenware sewer pipes over 15 in. diameter. For larger pipes, use cast-iron.

Railways on Peat Bogs or Swamps: Should your line cross a morass, peat-bog or swamp,

(1) Drain and side ditch where possible, and thus make bog firm enough to carry, in preference to cross logging. Ditches may be 5 feet deep, and, if possible, 20 to 50 feet from the centre line.

(2) Do not cross-log where bank is high and settlement likely to be considerable, only where bog is nearly but not quite sufficient to sustain the bank. The cross-logs broaden the base and form a light material for part of the bank; used in any other way, they are more harm than good.

(3) Keep grade low.

(4) Make banks as light as possible, using turf, peat, sawdust or cinders.

(5) If sides bulge up much, leave only 5 ft. berm between toe of blank and edge of ditch; but, if no bulging, make berm as wide as possible.

(6) If bog *cannot* be drained, then lengthen the wave motion by cross-logging; first tier 25′ to 40′ wide, laid longitudinally, second tier transversely. Fill interstices with turf; put three inches of sand over, then surface with cinders. If crust breaks through, fill with loose stones, as clay spreads out in the semi-liquid peat.

(7) In water and very soft mud, build cribs as wide as the bank will be at the point where you think the toe of the crib will come to rest. Put a close floor near the bottom. Let the weight of the cars containing the filling press the crib down into the mud, and keep building on the top and raising the track as it sinks. The more filling done into the crib before the train comes, the less track-lifting will be required.

Peat bogs usually contain 75% to 90% of water, and it is because of this excess of water that trees will not grow on them. The roots must breathe the air or the tree cannot live. In the Dismal Swamp, the roots of the trees grow in vertical curves, so that some part is always above water.

Settlement of Banks; Embankments will settle more or less, according to the materials. Settlement is from 2½% to 7%.

Loam settles most; clayey soil next; sand and gravel next

For embankments made by scrapers, allow 3%.

For embankments made by wheel scrapers allow 5 %.
Cars unloading from temporory trestles " 7%.

STONE MASONRY RETAINING WALLS :

3-7 of h over footings for bank level with top

1-2 " " " { surcharged wall
bad masonry
bank of bad material
very important wall
dry masonry

6-10 when any two of above exist together.

(See Eng. News, Jan. 26th, 1893.)

The line of pressure in a soil diverges from the vertical at half the angle ot repose.

(See Trans. Can. Soc. C. E., 1897).

In North America, put foundations down not less than 4′ to 6′ below the surface.

It sometimes happens that well-designed retaining walls are destroyed by pressure from a clay backing when the clay has seams of sand running through it. When an excavation is made these seams are exposed. In dry weather, cracks from the surface will penetrate downward until a horizontal sand layer is reached, and the sand will be carried out, leaving the clay surfaces to slide on each other. At Ste. Anne, in Quebec, whole farms have been destroyed in this way. In one case, a hill moved a ¼ of a mile, filled the river bed, and covered up a grist mill. At the Soulanges canal, the whole side slope of the canal slid in for ¼ of a mile, destroying a bridge and causing damage to the extent of $100,000.00. It was considered too expensive to build against this immense pressure, and the canal was dredged, leaving the ragged side as it fell.

APPROXIMATE ESTIMATES : You have a ravine to cross with a steel trestle, and you want a quick estimate of the cost. See Plate I, Fig 3.

Area of A B C D E in sq. ft × 8½ = lbs. of metal in towers and bracing.

8½ for a viaduct 100 feet high
9½ " " 50 "
10½ " " 30 "

Girders in lbs. per foot of span is (9L + 100).
Estimate at 5 cts. per lb. erected.

TIMBER TRESTLES:

Height 10 ft. – 25,700 ft. B. M. per 100 lin. ft.
" 20 " = 30,500 do.
" 30 " = 38,600 do.
40 " = 47,000 do.
" 50 " = 55,200 do.

Cost of timber per B. M. = \$17.00 to \$27.00
Labour on timber " " = 6.00 to 7.00
Wrought iron = .06
Cast iron = .03
Stone masonry per cu. yd. = 8.00
Concrete = 6.00

PAINTING BRIDGES: As a rule, metal bridges suffer for lack of paint. The best paint for metal work exposed to its greatest enemy —salt air or salt spray is :

$\left.\begin{array}{l}\frac{1}{2}\text{ red lead by measure}\\ \frac{1}{2}\text{ iron oxide}\end{array}\right\}$ for 1st coat

Iron oxide for second coat.

When subjected to salt spray, scrape and paint once a year. One pound covers 6 square feet of surface. For steel exposed to locomotive gases, use a mixture of red lead, Portland cement and linseed oil, put on $\frac{1}{4}$ in. thick with a trowel : costs 8 cts. per square foot. See Eng. News, 24th April, 1902.

No paint should be applied to a damp surface, or at a temperature below 40 degrees Fah.

A very good iron oxide paint is sample No. 103, Leach, Neal & Co., Ltd., Derby, Eng.—$2\frac{3}{4}$ cts. per lb. in St. John, N. B.

WHARVES: If you have a wharf to build where large steamers will discharge, it will be well to know that in New York, 500 lbs. per square foot is standard loading for wharves ; and this necessitates piles to be driven 6 feet centre to centre transversely, and 8 feet centre to centre longitudinally.

San Francisco pile wharves are designed for 250 lbs. per square foot of floor, with a safety factor of 4.

Philadelphia ....do. for 700 lbs. per sq. ft.—safety 3.
Boston & New York...do. for 400 to 600 lbs. " — " 5.
Boston ....do. for 300 lbs. per sq ft. —

(See Engineering Record 8th, 15th, & 29th June, 1890).

For warehouses on wharves where steamers discharge and goods are piled on the floors of the warehouse, it seems to me that the floors should be designed for not less than 400 lbs. per square foot, evenly distributed.

At St. John, the I. C. R. has a fine terminal wharf and warehouse the floor of which is designed for 250 lbs. per sq. foot and the roof for 60 lbs. per square foot.

GRAIN BINS: There is also a grain elevator at St. John; and, in case you should have anything to do with designing grain bins or coal bins, it would be well to note that, according to recent experiments, the pressure on the bottom of a grain bin is not that from the whole height of the grain, but from a cone-shaped mass, the height of which cone is almost exactly one-half the perimeter. The pressure against the sides should be calculated on the hydraulic theory.

Formula for weight on bottom:

$$P = A\,C\,D\,W = 1.03\,ADW$$

$$\text{or} \quad \frac{P}{A} = C\,D\,W = 1.03\,DW$$

$P = 1.03\,ADW$
A = Area of bottom in sq. ft
D = Diameter of inscribed circle in feet
C = A constant determined by experiment, = 1.03.
W = Weight of a cubic foot of wheat, = 48.6 lbs.

RAILS: Steel rails are a very important part of a railway. The best chemical specification for steel rails, so far as at present known, is:—

Carbon	0.42%
Silicon	0.10%
Sulphur, Max.	0.08%
Phosphorus, Max.	0.075%
Manganese, Max.	0.100

ANGLE BARS: Some American specifications call for carbon as high as .6 %; but Sandberg, the best authority on rails, gives actual figures from breakages in Sweden to prove that anything over .42 % carbon is undesirable, and also proves that phosphorus over .75 % is injurious. Carbon hardens the rail, and phosphorus makes it brittle and liable to break in cold weather.

TRACK: The tendency is to use heavier rails as traffic increases. Adding to a 60 lb. rail increases

	Weight	Stiffness	Strength	Durability.
10 lbs. per yard	16.7%	36%	26%	83%
20 " "	33.3%	79%	54%	167%

Rails become unservicable when 1-5 of the head is worn away.

RAIL-JOINTS: The best rail-joint for this country, in my opinion is the 6-bolt, 3-tie supported joint. A rail-joint is the last place where rigid economy should be practiced, for, no matter how good the body of the rail is, the track is no better than the joints are.

RAILS,—CARBON: The danger of high carbon in steel rails is shown by observations in Sweden from 1872 to 1901, = 29 years.

Cammell's rails with 0.42% carbon—fractures were	0.24	per 10,000 rails	
" " " 0.50% " — " "	11 56		
Barrow rails with 0 42% carbon—fractures were	1.27	do.	
" " " 0 48% " — " "	7 20		

RAILS—HIGH PHOSPHORUS: The danger of high phosphorus is shown thus:

In Krupp's rails, carbon	0 28, phosphorus	.090 = 30.62	fractures per 1,000 rails
In Rhymney's " "	0 42, "	.069 = 7.60	

Both 22 years laid.

Bessemer basic steel rails are unreliable.

Union German rails—carbon 0.32%, phosphorus 0.076%, show 25.53% of fractures per 10,000 rails.

Rails used in England and Sweden are made of Bessemer acid steel, from pure ores.

TRACK TIES: The life of railway ties is in this country:

Tamarac	9 years (very scarce).
Prince's pine	8 "
Cedar	6 to 10 years
Hemlock	7 "
Black Spruce	6 "
White Spruce	4 "
Red pine	4 "
Fir	3 "

Some people have numberless ideas rolling around loosely in their heads without the power to put them to any practical use, or even work them out far enough to demonstrate either their value or their absurdity, as the case may be. They will spend hours in telling you how things might be done, without even thinking of working them out on paper and estimating their cost. Perhaps an hour's work with pencil and paper will prove the scheme to be either mechanically impracticable, or to be an absurdly expensive way of attaining the desired end.

In cases of emergency, such as arise on railways when bridges, culverts and road-beds are washed away, and repairs have to be made on short notice and with little means, the resourceful man is then at his best. This man is one who has native intuitions, is a close observer, no boaster, a man of judgement and tact, and one who will benefit by the experience of others as well as his own. To this person,quick and cheap methods of doing things in an emergency will suggest themselves

Occasions may arise when you will also be called upon to think and act quickly. If you are men of resource, you will, with a very limited outfit, accomplish more than ordinary persons with everything to hand.

Once upon a time, the Chief Engineer of a railway and his master worked all day driving piles and building up cribwork, to prevent a stream from carrying away an embankment and stoping traffic. In the evening, their construction had gone the way of all the earth. A farmer who had been sitting on the fence watching the proceedings then came over to the engineer and very modestly said that he thought he could "fix it." He was told to try his hand. He ordered 3 or 4 of the men to go over to the hillside, cut some brush and bring it down. Going to the foot of the bank, he threw the brush down where the water was scouring, shingling it on, one piece overlapping the other, and staking each piece in place, until in an hour the scouring was arrested and the bank saved. None of us "know it all", and the engineer who is not all his life a scholar will very soon become fossilized and degenerate into a back number.

Bismark once said that he generally managed to profit by the experience of others rather than his own; and, remembering the farmer and his brush, it once came my way to check a stream in its endeavours to destroy things. The track-master, who had an engine and train at his command, said—"We want a train-load of "stone thrown in there, and I can get it three miles away." I asked him to leave six men and a hand car, and I would make a little experiment of my own while he was gone. You will observe I said nothing about having borrowed ideas on the subject. Cutting a number of spruce trees about 6 in. in diameter and 20 feet high a short distance away, I transported them on the hand-car and rolled them off down the bank into the water, fastening each one with a piece of fence-wire to the track-ties and shingling them along one outside the other. By the time the trackmaster and his train of stone returned, the whole trouble was over, and, although the stone was thrown in, there was no necessity for it. Since that time. I have had enough assurance to think that, with some spruce brush, a little fence-wire and enough rough logs, I could very quickly get over any wash-out likely to occur on a railway. The common woven fence-wire is a very useful article in cases of emergency You can take a web of it, cut it down the middle, and roll it up into a cable which a locomotive could not break. If you want to climb a cliff to get an overhanging dangerous rock down, send a man around the hill with a coil of the wire, and have him throw one end from the top, fastening the other securely ; then use it as a ladder. Do you want heavy rip-rap, to put around a pier which the current is trying to scour under and destroy? Do not telegraph to headquarters for 100 yards of quarry stone, which it would take a month to get ; but take a web of this wire and cut it into pieces large enough to form bags holding each one or two bushels of small stones which you can get almost anywhere, and, when you have closed the bags by twisting a few wires together, dump a lot of them down one on top of the other, and the current may do its worst, but it cannot displace these bags of stone. English engineers have done this very successfully years ago in India ; but that was before the days of fence-wire, and their bags were made of hemp ropes. If you cannot get the stones or the fence-wire, then keep the telegraph wires hot until you get a few barrels of Portland cement. A lot of one-bushel bags can be gotten almost anywhere, and sand is usually somewhere near at hand. Take one part of cement and six or seven of sand, mix them thoroughly, dry, fill the bags, tie them securely, and dump them into the water. In a few hours, you will have the best riprap which it is possible to make and your pier will be saved. This reminds me of other uses to which fence wire may be put.

One of the abutments of the Bedford bridge, near Halifax, built in 1858, was badly tracked and showed signs of general collapse. Those who thought they knew said "*Take it down and rebuild it.*"

Now, I dislike taking things down, and I lost four or five hours sleep one night studying out a plan to avoid tearing it to pieces. The plan worked out to perfection, which is an unusual thing for plans made in the silent watches of the night. I drilled holes from side to side of the abutment and put three long rods through, 1½ in. diameter. Next, I pointed up all the joints with cement. Next, covered it with a four-inch mesh netting of No. 9 wires, laid on vertically and horizontally. Next, filled the interstices of the abutment with cement grout, poured into drilled holes at the top ; and cased up the whole outside with 18 inches of concrete making a perfect piece of work. Some wise people from Halifax, who were summering at Bedford and seeking a little relaxation, thought it their duty to notify our General Manager that he could not surely be aware of the childish things that were being done at Bedford by his subordinates, and that they were actually trying to keep up the abutment with telegraph wire. Soon, you young men, who are now in this room, will be the men in our places, doing work of the same kind which we older men are now doing as best we can, and you will do it more perfectly and with much greater ease. Your advantages are, and will be, better. You start out better finished. You have the experiences of others behind you. You will avoid their mistakes and profit by their successes. Your professors are up to date and can give you the latest information on all the subjects taught. Notwithstanding all this, success will always and forever depend entirely upon yourselves. If you are willing to work hard and study as you go, to work at any sort of drudgery which comes nearest, thus fitting yourselves for, and always being able to efficiently fill, a better position when it comes ; this, coupled with honesty, truthfulness and a character above reproach, will *compel* success in the noble profession of the Civil Engineers.

Construction of the Fish River Branch

OF THE

BANGOR AND AROOSTOOK RAILWAY.

Moses Burpee, Chief Engineer B. & A. Ry.

MARCH 20TH, 1903.

THE B. & A. R. R. System now includes a line built as the Bangor & Piscataquis between 1870 and 1880 from Old Town to Greenville, 76 miles, with a branch from Milo Junction to Katahdin Iron Works, 19 miles. The elevation at Old Town is about 100.0 above sea level, and at Greenville about 1030.0 involving a considerable rise near the head of the Piscataquis Valley where in one continuous incline about 12¾ miles long the elevation rises from 450.0 to 1068.0. This occurs between 54.5 and 67.3 miles and crosses the water shed between the Penobscot and Kenebec rivers. The latter is reached at Moosehead Lake, at the southern end of which the town of Greenville is located. The rise from 100.0 to 450.0 is very gradual and undulating, being made in a distance as above indicated of 54.5 miles.

The first 50 miles or so of the line has good alignment as well as easy grades, but in the upper part of the valley where a long gradient must be developed in the surface of the country, it must conform to such alignment as is afforded by a quite steep bank on the east and north slope of the Piscataquis Valley.

The Katahdin Iron Works Branch follows the Pleasant River, a branch of the Piscataquis, has no heavy grades nor interesting features

The B. & A. R. R. Co., which now owns the above-mentioned roads, was organized in 1891 to build from a point on the Katahdin Iron Works R. R. near Brownville through Piscataquis, Penobscot and Aroostook Counties to the St. John River at Van Buren and Fort Kent. The location does not follow any large valley, but crosses the water sheds between several branches of the Penobscot, and comes into the valley of St. John in the Town of Smyrna about 15 miles west of Houlton, the summit elevation here being about 645.0. The elevation at Houlton is 360.0. From this the course is northerly coming to the valley of the Aroostook River at Presque Isle, and following this river to Caribou, crossing to the north side about a mile north of Presque Isle by a bridge 810 ft. long. At Caribou it diverges to the northwest and crosses the plateau of the St. John Valley to the head of Violette Brook, which it descends to Van Buren. The elevation of St. John River at this terminus is about 450.0, but that of the summit between Caribou and Van Buren is about 750.0.

The branch which runs to Fort Kent leaves the main line 16 miles west of Houlton in the town of Oakfield, and runs in a general northerly course, following the valley of the East branch of Mattawamkeag to its head. Then with no appreciable rise crosses the water shed to St. Croix Stream which is followed to its debouchment into the Aroostook at Masardis. Ten miles farther is Ashland, the terminus of this branch until last year and 43 miles from the Junction.

om Ashland to Fort Kent is 52 miles. About one mile north of hland the line crosses Aroostook River. The bridge is a Deck Pratt truss, 4 spans 152.5 feet C. to C. of piers, with 83.5 feet of viaduct approach at each end, making a total of 777 feet. The masonry of this bridge was begun in December 1901 and finished in March 1902, work continuing through the freezing weather with no break. Water was heated for mixing cement, mortar and concrete.

Sand and gravel also were heated. The method for heating the latter was by using a large flue about 2 ft. in diameter and 10 ft. long, placing it on the gravel piles with one end slightly elevated, and building a fire of cord wood in the lower end. It was then buried as completely as possible with the gravel or sand to be heated. From this pile of hot gravel or sand, it was taken for use, the same being replenished forthwith. As the heat is retained well by this material, there was very little trouble in keeping a supply on hand continually. No salt was used in any of this mortar.

In the improvements made on the B. & A. R. R rather more masonry has been built in winter than in summer, but where Portland Cement has been used, no bad results from winter work have been observed. A small quantity of Rosendale (A Natural Cement) was used at the beginning of construction 10 years ago, but good quality of Portland is now easily obtained, and I think is more economical than natural cement, and far better for structures which must carry their load shortly after completion, and for winter work. This however is a digression.

The South abutment and pier 1 in Aroostook Bridge are of granite masonry wholly, as they are on dry foundations. Piers 2 & 3 have concrete bases under water. The bottom of the river was found good and of sufficient solidity for the support of the piers. The only precaution adopted having been to lengthen and widen the bottom of the foundation so as to give sufficient surface for one square foot to every two tons or so of load. The material under the S. abutment is a layer of gravel about 4 ft. thick. Under pier 1 is a very hard and heavy clay, in the bed of the river a hard pan of gravel with clay.

It may be worth while to describe a tool which was used for driving the steel bars used in testing the river bottom to ascertain its consistency, as it was both simple and effective. In the first place a pointed steel bar was started in the usual way and driven to the level of water by a heavy sledge, when the driver was put into use to follow it below water. This was formed of a piece of piping about 18″ long and large enough to slip over the sounding bar loosely. The bottom end was left open, and into the top was welded a piece of bar of convenient length, serving as a plug to close the end of pipe and also a handle by which to operate it. This was churned up and down on the rod, and by its weight, but 40 lbs. the sounding rod was driven readily. It should also be noted that this operation was very conveniently carried on from the ice. I had at first expected to be obliged to drive piles, but the consistency of the material was deemed not only capable of carrying the load, but also of destroying piles in the attempt to drive them, which attempt it was deemed would also have resulted in disturbing the bottom under the pier, and rendering it less firm than more so.

Caissons or moulds for the concrete bases were sunk at their precise locations as nearly as possible. These were built of 6 × 8 inch spruce lumber and the bottom course had two iron tie rods to prevent its spreading. These caissons had a batter of 2″ to the foot, and of course were open at bottom and top. Care was taken to fit the bottom edges to the bed of the river, and in one case where not successful in this, sacks of concrete were laid on the bottom just outside the caisson to prevent the loose concrete flowing out from within. I have heard of depositing dry concrete in sacks for such purposes, but while not thinking it worth the trouble decided to put it to test. The result was that the water never got a great way into the mass, but a thin shell at the outside appeared to set before the water could penetrate the mass. The concrete was mixed by hand on a platform beside the pier, shoveled into boxes holding a cubic yard each, and the box was then lowered by derrick into place. The bottom of the box was made of two leaves hinged on the opposite edges, and kept closed by a latch, to which a tag line was attached. On the box reaching bottom the tag line was pulled, releasing the latch and the box hoisted for another charge. After the concrete was dumped it was somewhat flattened out by a pole on which a wooden shoe was nailed at its foot. The idea was to avoid punching holes in the concrete, but to press it down somewhat, especially at the edges just within the caisson.

Pier 4 was at the water's edge and no caisson was used. Pier 5 was similar to pier 1 in construction, and the north abutment was laid on a gravel bed. There was a pair of pedestals between the abutments and nearest piers on each end. The foundations above described are at the top somewhat larger than the neat work which superposes them, and on these, when laid to the intended height, the lay out of masonry was carefully made and corrected if necessary.

Owing to the erection coming on when the ice might have been expected to run out, it was decided to erect the superstructure on the cantilever plan. Accordingly one of the spans was erected on land south of pier 1, the south abutment having been left off at a level about a foot below bottom chord of truss. To this was added about 30 tons of rails to counterbalance the traveller and working outfit and give a little additional stability. It was planned so that the north end of the truss when erected should be a few inches higher than its normal position. This was affected by placing an iron block called the “Kicker” between the feet of north end post of Span 1 and south end post of Span 2. The end posts are vertical and a hinge which embraces the extended ends of the end pins in top chord on each side. This hinge held the tops of the end posts of the adjoining trusses together and of course temporarily reversed the stresses in the truss chords, and created the necessity for special features in the design. The additional cost due to this was estimated to have been compensated by the saving in false work or trestling for the support of the structure during erection. To lower the other end of truss on to its pier, it was first jacked up so as to release the kickers and then lowered on to its shoes, after which the hinges were removed from top chord.

The masonry in Aroostook Bridge contains 1390 C. Ys. Ashlar.
" " " " 473 " Concrete.
The superstructure about 600 tons of steel

A low summit between Aroostook and Fish River waters crosses within 10 miles of Ashland and the line touches the latter at Portage Lake 11.6 miles from Ashland with elevation of road about 628.0. Between this and Fort Kent the Fish River is crossed twice, once at the 30th and again at the 49th mile.

The first crossing of Fish River is a two span deck girder, each span 90 ft. long. It is on a skew of 50 and the grade is 52 ft. above the bed of the river. Perhaps the only unusual or interesting feature in this bridge is the large size of the abutments. The steep banks on each side with considerable cutting which gave material for the embankment approaches, was one reason for shortening the opening and necessitated massive abutments. Usually there is economy in the amount of masonry where the use of additional short girders permits very small abutments being made, thus practically filling the ravine with bridge work. In this case it figured about evenly when the cost of temporary trestling and the waste of embankment material were considered. Besides, the advantage of a short bridge over a long one in cost of maintenance as well as safety caused the decision in favor of the method adopted. The angle of skew also determined the plan of building the pier to the height of bottom of girder instead of using trestle to support the girders as might have been done at a square crossing. The total amount of concrete in this bridge is 3126 cubic yards and the amount of Portland cement used 4060 barrels.

The foundations are all on rock. The south abutment foundation nearly level. A coffer dam was used for the front part, but the wings were nearly all above the level of the water. The abutments are the kind known as U abutments. The north abutment has the front part in about 6 feet of water at ordinary stages. But little dirt had to be removed, and it was done with a common scraper with poles about 10 feet long for handles. It was drawn by a line passing through a snatch block and operated by a hoisting engine. Two men, one at each handle and walking on floating walks on either side the ground to be scraped, placed the scraper and steadied it while being drawn by the line. A dump was made a little below the down stream end of foundation, and on to this the scraper was emptied each trip. The bank under the wings of this abutment also was ledge and this was stepped in jogs of about 4½ ft. At the pier foundation there was about the same depth of water, and as usual a coffer dam was driven around the site of foundation to aid in cleaning off the two or three feet of dirt and gravel overlying the work. It was found however impossible to pump the coffer dam out owing to the water coming through the gravelly bottom under the foot of the sheet piling. Therefore the down river end of the coffer dam was taken out and the sides secured by guys to each shore so as to permit removal of all interior supports, and the scraper was brought into use again, dragging it from the upper end of the foundation and dumping the contents entirely outside the coffer dam. It is probable that if it had been foreseen that the use of scraper would have been made, the coffer dam would not have been made as such, but the bottom cleaned off, and a caisson or mould for the concrete sunk in position as was done at Aroostook Bridge. There are however but few works done in which unknown conditions do not arise, and in such, experience and knowlege of expedients is very valuable. In each foundation a footing course of concrete was laid, having a slight margin or offset more for the sake of giving facility for precise laying out of the work, than for greater area, as the rock bottom did not require the latter. It is seldom that the foundations can be laid with great precision owing to difficulites in placing coffer dams or caissons with exactness or holding them in position, but a little margin allows corrections to be made even if it does not serve any other purpose. Usually, however the footing courses are broader for the purpose of distributing the weight over a larger area than the bottom of the neat work of pier or abutment, but as will be seen it serves the other purpose also.

In order to carry the track which usually must be laid long before the superstructure is erected, a temporary trestle was built. In fact the girders were not put on until after the opening of the road for business. These girders being [illegible]' 9" long and weighing about 21½ tons each were carried on three cars. All the weight however placed on the extreme cars, the middle one being what is called an idler, simply used for the sake of continuity in the train. So far as the weight was concerned [illegible] might have carried it all, or 2 girders might have been loaded on the 3 cars, but there would have occurred complications by doing the latter, which might have made the transportation and erection much more expensive than by using three cars for each. In all such work it is well to adopt the greatest simplicity possible, and allow for any number of things happening otherwise than they ought.

In erecting the girders two gallows frames were used. They were placed one near each end of the span and supported on one of the caps of trestle arranged for the purpose. These frames when raised into position were guyed so as to maintain an upright position. A set of double blocks was hung at each end of the cap of each frame, 4 sets in all. The train with the girder was brought into position under the gallows frames, and a grapple caught on at the upper flange of the girder at each end. Then all 4 sets of blocks were set to work to raise the girder from the cars. When this was done the train was drawn clear off the bridge, and the girder was lowered into place. Being held by 4 blocks it was possible by lowering faster on one side than the other to carry the girder over to the side to which it belonged Then the girder of the span was placed in the same manner, and the lateral bracing and the frames placed, and temporarily secured by erection bolts so called. These were in turn replaced one by one with rivets as a permanent connection between the girders and of the lateral bracing. These girders are spaced 10′ centers, and the floor laid directly on the top flanges.

The first crossing of Fish River is below the outlet of Nadeau or St. Froid Lake, the bank of which the line follows for about 8 miles. About 2½ miles north of the crossing it first touches Eagle Lake, the shores of which it follows about 6 miles to to the outlet, and thence to Fort Kent the location is for a greater part of the distance on side of east bank of Fish River and rock cuts are frequent, curves sharp and tangents short. Before reaching the 2nd crossing of Fish River it crosses the Wallagrass by a through girder of 75 foot span.

The second crossing is apparently much the same as the first already described, but not quite so high, being 39 feet from grade to bed of river. The angle of skew is 55°, and there are 3 spans 90′ each. The north abutment is on rock, but the south and the two piers are on pile foundations. In these the piles were cut off some distance above river bed, and the caisson placed so as to enclose them, and the concrete deposited as described at the Aroostook

Bridge to the level of the water surface, where a new and precise layout for the neat work and its moulds was made. The amount of concrete in this bridge is 2211 cubic yards and the number of barrels of Portland cement used was 2580

Perley Brook Arch near Fort Kent is entirely of concrete. It is 18 foot span. The arch is segmental and has a rise of one-fourth the span. The walls are 6 feet high. The invert has a spring of 1 foot, thus the total height at centre of span is 11.5 feet. It contains 630 cubic yards of concrete and there were used in its construction 608 barrels of Portland cement. In designing it care was taken to avoid complicated structure of moulds, which would have considerably increased its cost. Across the ends from wing to wing a thin curtain wall is carried to a level of 5 ft. below the invert. In the massive parts of the walls especially below the invert, boulders were deposited with the concrete so as to economize in cement where bulk and weight were required and no tensile stress possible. In the arch however the best quality of concrete possible was used, and a greater liberality in proportioning the cement. The quality of gravel used in this was excellent and this largely accounts for the economy in cement.

The method of depositing cement under water by boxes with valve bottoms has been described. This was not used entirely in the work above water. Another method in which a gravity concrete mixer was used, was to take it directly from the mixer into a wheel barrow and wheel it to the desired place and dump. Wheel planks were laid in a circuit and as many barrows used as could be supplied with the concrete. With this mixer it is necessary to have a platform 10 or 12 ft. higher than the level of the work. This platform is large enough to mix 2 batches. A layer of gravel is laid on this [illegible] the necessary amount of sand on that, and then the cement. If the gravel and sand have previously been wetted, the mixing is much facilitated. This mass is then shoveled from the bottom and thrown into the hopper of the mixer, the water turned on and mixing is done in its descent. A gate at the bottom is kept closed except when the wheelbarrow or other receptacle is in place. A man is stationed at the lower end to attend to the letting on or shutting off water, and to open the gate to deliver mixed concrete. There are well known rules for proportioning the ingredients to be mixed, but in the use of gravel it is found that a trial for the proper proportion would better always be made. When possible to select gravel it is best to use such as has the greatest range of sizes possible so that the interstices between the largest pebbles are filled with smaller ones, and the interstices between these with a still smaller size, and so on until sand fills the last of them, then once and a half or two times as much bulk as is represented by the mass of little interstices or pores must be the measure for cement mixed with water. It will be apparent that thorough mixing is necessary for the best result and this is only completed when also thoroughly rammed.

In building thick and heavy walls, large boulders were frequently used where they could be properly placed. It is of course always necessary that these be clean, and it is also better that they be wetted before placing them.

In regard to whether concrete should be very wet or only slightly wet there has been a good deal of discussion, but I think experience has shown that it would need be wetter than the old rule would allow. My opinion is that it ought to be wet enough to flatten out pretty well when deposited, and yet not so wet but that it could be appreciably compacted by ramming. This is shown by the water rising to the surface of concrete after being rammed, which is an evidence that the mass of voids between the solid ingredients has been reduced.

I have as yet said nothing about the survey, clearing, grading and building culverts, and as no doubt you will be somewhat interested in this I will speak a few minutes on it. The features of the country practically make it impossible to choose other than to follow the valley quite closely. The summit between Aroostook and Fish River of course is an exception but even here the rule holds good, for the valley of the Little Machias affords the best route. The method adopted after reconnoissance was made was to place three parties in the field. One from Ashland to the middle of Nadeau Lake, the second from this point to the Wallagrass Stream, and the third thence to Fort Kent. The first party after reaching Portage Lake made use of boats largely for transportation of supplies, and although covering more than half the line, had not so many complications in natural features as the others. The Fort Kent end especially was difficult, and even after a fairly good location was laid down it was revised to advantage, and much excavation saved

The personnel of the party is, engineer, transit man, two chainmen, rear flag, leveler, rodman, 4 or 5 axmen, cook and cookee. Assistant Engineer has charge of all the men, and lays out the location on map, as well as making side explorations to determine whether or not improvements can be made. Transit man in absence of the engineer has charge of the field operations of the crew. His men are the axmen who clear the line of brush or trees in wooded country, on the line projected by him, but in clear land they make and drive the stakes. The number of axmen varies from three to six. There are two chainmen who follow the line cleared by the axmen, in wooded country making and driving their own stakes. The head chainman carries a ranging rod or flag with which he marks the end of each chain of 100 feet, setting it also on line as given by the transit man. The rear chainman holds the rear end of the chain at the stake last set until the next stake or station is set. A rear flagman remains at the next hub or transit point behind the transit in order to give by a pointed ranging rod held on the take in hub the back sight to the transit man. In setting a hub at the forward end of the sight the transit man gives to the head chainman a line for hub, and after this has been driven he repeats the operation with great care after checking his transit on the back sight, ni order to set a tack in the hub The head of this tack is the point over which the plumb bob of transit must hang when set up. After the transit line has been run say a thousand feet or so the leveler and rod man take up their work. The first thing done is to establish a bench mark, to which is given an arbitrary elevation, unless there be an established datum in the neighborhood. All levels are referred to the datum thus adopted.

In construction the 51 miles were divided between nine Assistant Engineers, whose first duty was to stake out the widths for clearing of woods. After clearing had been completed the line and levels were checked and the staking out or cross-sectioning of the cuts and fills, and the laying out of culverts was done. Each assistant was previously furnished with a profile and plan of his section, by the Chief Engineer, this having been made from the notes of the locating engineers. On this was shown the depth of cuts and fills at the different stations and the size of culvert openings recommended. Monthly measurements of work done by the contractor were made at the end of the month and recorded in the measurement book.

From these records the detail monthly estimates were made, and these furnished the basis for monthly payments to the contractor.

The following description of tracklaying and ballasting in general will apply to this case. After the completion of grading the centre line is re-staked for tracklayers rather more carefully than for the grading, and after track has been laid, again for the ballasting in which also precise grades to which the top of rail will be raised.

Track laying consists in putting down first the ties, usually cedar, on the grade, lining them to the stakes and then on them placing and spiking the rails. These are brought to the end of track on flat cars, unloaded, a car at a time, the train backed away and a small lorry brought along side the rail pile, loaded with rails and pushed along by a crew of men who also unloaded and place end to end the rails, one at a time. One half the crew do this on each side the car. Just behind the lorry are a crew of men who put on the rail splices and put in two of the four bolts in each. These are followed by others with wrenches, the first set screwing up the two bolts first put in, while others follow to put in the remainder of the bolts and screw them up. It is important to leave some expansion between the rail ends, unless the temperature at the time happens to be extremely high, and even then a little is required to allow for the taking up due to the roughness of the unballasted grade.

Ballast should be the best possible gravel obtainable for the purpose and the more the better, up to at least two feet or so in depth, although one foot is usual. Its object is to furnish a uniform, porous and easily drained bed for the ties. Any material next under the ties which moisture will liquify, as clay for instance, would in a short time become displaced by washing out, and would also in winter expand in freezing so as to "heave" the track very much out of surface. The latter is also caused by insufficient ballasting, or the gradual mixing of the gravel ballast with the clay underneath it.

Ballasting operations are as follows: A track is laid into a pit of gravel, and a train standing on this track is loaded with gravel either by men or by a steam shovel. This loaded train is then hauled to the track requiring ballasting, and unloaded by men or by an unloading plow standing on the car farthest from the engine and headed towards it. A wire rope is attached at one end to the plow and the other to the engine, the brakes which are rigged on the sides instead of on the end of cars are set up so as to hold the train in place, while the engine pulls the plow over the train, dividing the gravel and pushing it off each side the cars. The gravel as thus distributed along the track is used for tamping under the ties which have been raised to rail or ballast grade.

The track is raised by ratchet jacks to the desired height, determined by the lifter using sight blocks and sighting towards a straight edge, set on the rail height stake ahead, and while held by the Jack the tie next to it is tamped solidly, then the Jack is moved ahead and the remaining ties tamped and gravel filled between and under them. From 50 to 100 men may be employed in one gang at this work. There are also self dumping or unloading cars used for distributing ballast, and these are coming into increased use each year, owing to their carrying larger loads and distributing more evenly.

Finally mile and signal posts for the convenience of operation are set along the line.

As I meet so large a class of young men preparing for the practise of Civil Engineering, I am reminded of the remark which I have frequently heard, viz.: that Engineering is overdone. This does not appear to have much influence just at present, for there is a demand which even exceeds the supply ; due of course to the increasing demand for the building of railroads, canals and manufacturing plants. This may tempt many young men into the study of the profession, but I think there is something in the life of an engineer that appeals strongly to the taste of a large proportion of young men, and this may lead many to choose the profession, regardless of a due consideration of the future. I think it is evident that a large increase in the number of practising engineers will require that they adapt themselves to a broader field or that they include a greater number of specialities among which to distribute their work.

It is a duty of every man to contribute something to the public good or enhance the value of the property of his community. No man is better fitted to do either of these than the engineer, as his profession is almost entirely devoted to the improvement of properties or the creation of them. Therefore he is an important member of society, and it will have been well that in preparing himself for the practise of the profession, if he has also prepared himself to fill with credit the highest positions in society. Professional skill is necessary, but good character is no less so. The relation of character to habit is that of effect to cause. No useless or bad habit can result well, nor can good habits end badly. While professional skill and good character are indispensible to the engineer, he should remember that these are but the foundation of his ability to fully satisfy the requirements of society, and unless he cultivates the qualities which enable him to harmonize with his surroundings, he does not come much nearer to fulfilling his true mission, than does the foundation of a mansion the purpose of the elegant structure contemplated.

Engineers are usually responsible for the execution of work involving large expenditures, and have in their hands the interests of a large number of persons It is well then that they should study carefully the rules and principles of organization, and that after having determined the mechanical features, they should combine in a harmonious manner the various efforts of those who are to co-operate, so that there be no waste of money through one man working against another, or even duplicating needlessly another's effort. The ability to do this part of the work successfully is I believe the distinctive characteristic of the most successful men in any calling. No doubt a knowledge of human nature is necessary, and I believe also is the fair and generous treatment of one's fellow workers.

There should also be in the engineer the ability to size up his work properly so that he shall estimate correctly the relative importance of different matters. It would tend to loss if he should neglect vital necessities and spend much time on affairs of little importance. You will remember the illustration of Captain Phoenix survey of a cir-ular track, viz.: pacing off the diameter and multiplying by Pi ex-ressed in seven places of decimals Precision is well, but accuracy better. One should have the habit of being correct in his work, nd precise in places where slight errors would multiply by repiti-on, and yet should know how much in each case to spend in order get the desired degree of perfection. It is possible sometimes to tirely balk progress or to ruin enterprises by an unreasonable quirement for precision. Because one cannot attain perfection his work is no reason why he should not do the best he can. he leave matters better than he found them, he has prepared the y for some one coming after to make still further improvements. The engineer should have his mental vision always open to the uth, and should lose no time in discarding any theory or implement when a better one is possible. I have in mind now the failure of a large steel rail plant installed with rolls which were years behind the best practise. They cost but little, but were worth less than nothing in competition with modern plants. It may cost a pang or two for us to give up long cherished ideas or methods, but one must keep up with the times; always discerning the difference between means and ends.

The engineer should possess as complete a knowledge as possible of the natural resources of the country about him, for this is the field he is to develope, his mission in society being to minister to its needs and assist in the cultivation of that which will be of greater service, increasing its commercial and political influence by making possible the increase of population and wealth. It may be that this has been and still is left too much for those who have no higher motive for this result than the accumulation of luxury for themselves, and these, though they have done well, might have done better in one way with a more altruistic motive and in another if they had had better practical information as to how to install their enterprises.

There is, I believe, no education given which better fits a man to accomplish greater things for the state in which he lives than that given to Engineers. I think therefore your outlook should be broad, and although many of you may attach yourselves to corporations in the business of manufacturing or transportation, there should be a respectable proportion of you who will devote yourselves to the originating of industries for the development of your Country and the organization of the natural resources and forces about you into vast wealth producing systems.

The command God gave to man at the creation to subdue the earth and make it fruitful still challenges man's attention, and comes now with even greater force, because of your fitting for the work, to you than it does to others.

Canada has always furnished a fair share of engineering enterprises, and today offers a magnificient field for the employment of your skill. Although the world is your fair field, yet your native country will and ought to have your best services, and I feel sure that no profession shall outstrip our own in contributing to the material and moral improvement of our country, and I may not see it, but I think some of you will see the time when Canada's influence in matters of world importance shall be among the strongest

Relation of Geology to Engineering.

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IT may seem a little presumptuous for one who is certainly not an Engineer to attempt to address an assemblage of those who are either already making or who intend to make Engineering their profession, upon any topic properly belonging to the latter. Apart from my duties as a teacher my labours have been mainly directed to the field of geological exploration. Yet a little reflection will, I think, convince you that the two subjects of geology and engineering are not so widely separated as at a first glance they might be supposed to be.

Then both the geologist and the engineer have the surface of this terrestrial globe as the theatre of their operations ; both have to take careful account of the varying characteristics of that surface ; both require, by means of instrumental surveys, to fix the relations of different portions to each other, and the heights of each above given datum-lines ; both have to take account of the soil-mantle which cover more or less deeply the rocky crust of the earth ; both have to pay some attention to the rocks as regards their nature, their composition their structural peculiarities and their arrangement. Finally both, in the course of their exploration, have to find their way through trackless wilds, to climb high mountains, to wade through swamps and streams, to endure the unceasing attacks of insect pests, or after the day's labours, to enjoy the blaze of the camp fire.

Recognizing these common points of interest, and feeling that many of the facts which are constantly pressing themselves upon the attention of the geologist, would if recognized, be of material service to the engineer, I have concluded to acquiesce in the urgent request of the Professor of Engineering and to bring before you this evening such thoughts as have occurred to me in this connection. I will begin with some reference to the work of the railway engineer, as being one of the most common and important.

And here the first topic which suggests itself is that of a *choice of location*. No doubt in theory, when two points are to be connected by road or railroad, the proper route would be the shortest line between them, and it is said that in the construction of some of the Russian railways, made under Imperial commands, that principle alone, irrespective of any difficulties which might beset its accomplishment, has been recognized; but not all railways are military ones, nor have all a Czar and his coffers to support the undertaking; and hence such routes must be chosen as will entail the least cost, not only in construction but in subsequent operation and maintenance.

And here we may notice that the first obstacle to be considered is that of relative levels and consequent steepness of gradients. It is not for me to tell you what the maximum slope may be, or what the numerical ratio between the angle of slope aud the power required to overcome it. But it may be worth while in passing to note that the differences of level to be overcome are very much less than the inequalities of the earth's surface would lead us to believe. For the very fact that the hills and mountain ranges of the earth are theprinciple condensers in the system of the earth's water supply makes then the starting-point of the streams and rivers which furrow the earth, and along these furrows a lower and more uniform level is to be attained than can be found elsewhere. Moreover the furrows upon opposite sides of mountain ranges often come close together and the divide between them, constituting a Pass, is much lower than the elevations which overlook it. Thus, on the line of the C. P. R. in British Columbia, Mt. Sir Donald in the Selkirks attains an elevation of 10,645 ft. and along the 49th parallel are several summits exceeding 10,000 ft. but the Kicking Horse Pass is only 5300 ft. Crow Nest Pass 5500 ft., and the Kootenay Passes between 6000 and 7000 ft.

Hence railways are apt, where possible, to follow the courses of rivers and streams, and their courses are the direct results of geological agencies.

These observations find good illustrations in the case of our provincial railways. Thus the Nerepis range of hills is intersected by four river valleys, those of the St. John, the Nerepis, the Magaguadavic and St. Croix, and, excepting the first, each is travelled by a line of rails; the I. C. R from St. John to Moncton is mainly confined to the valley of the Petitcodiac; the C. P. R. from Woodstock to Edmunston follows the windings of the upper St. John; the Gibson branch ascends the Keswick to descend again by the valley of Ackers Creek to Newburgh; the Canada Eastern similarly ascends the valleys of the Nashwaak and Cross Creek to the head of the divide and thence descends the long valley of the Miramichi to Chatham. It may be worth noticing also in this connection that where it is not possible to directly follow the present river-course, the track in several instances follows what was undoubtedly its channel in some earlier geological era. Thus the C. P. R. avoids the difficulties incidental to the cataract and gorge at the Grand-Falls by following an old pre-glacial channel now filled with drift; the road to Fort Fairfield does the same thing at the Aroostook falls; and again, near St. John, the course of the track from Grand Bay to Fairville is that of the main river in some remote period of its history.

In connection with this subject of the choice of routes it may not be without interest to examine the map now before you, prepared by Sanford Fleming at the time when the selection of the route of the I. C. R. was under consideration and which shows very strikingly the difference in the nature and seriousness of the difficulties to be encountered in each of the proposed alternative lines, their difficulties being all connected with geological causes. It may be especially noticed that while the I. C. R. and Temiscouata roads follow natural channels, the one descending from the Quebec Highlands by the way of the Temiscouata river and the other by the Metapedia, the newly proposed line of the Grand Trunk Pacific, if extended directly from Quebec to Moncton, will cross all the natural features of the country transversely and will meet with corresponding difficulties. From the general subject of the *choice of location* we may now pass on to consider some of the directions in which the *work of construction* is brought in relation with geological facts and principles.

And first as to the *formation of the road bed.* This may occupy positions which are very diverse in character. It may run along a river flat; it may skirt hillsides of various inclination; it may be at the foot of vertical bluffs or overhanging precipices; it may be tunneled through a solid rock; it may be supported on bridges or viaducts. And each of these situations has some features of a geological nature advantageous or disadvantageous, peculiar to itself. Thus, on a level flat construction is easy and cheap but apt to be tortuous. It is little more than ballasting and laying of rails, and so over prairie regions railway building can be carried on with great rapidity. But where the flat is traversed by a stream whose volume is liable to any great sudden or periodical increase, freshets of a very destructive character are likely to ensue, and lines of rails within their reach may become submerged or completely swept away in [illegible] short period of time. On the St. John river the rise of w[illegible] about 20 feet; in the Ohio it is about double this and with the increased volume comes increased velocity, giving to the current enormous eroding power. As a result of this change the C. P. R. is subject even in this Province, to a large outlay in maintaining its way, where the [illegible] Hartland comes close to the river channel. On the other hand, if situated on a hill-side, especially where the latter is steep and of incoherent materials, the tendency to the occurrence of *landslides* is often a very serious drawback. This phase of the subject is also well illustrated along the upper St. John, especially above Newburgh, for several miles below Perth, and between Aroostook Junction and Grand Falls. In places the hill-sides here composed of loose materials must be [illegible] 200 feet high and the slope is very steep and threatening, but though, after heavy rains, washouts do occur and in some instances have been attended with dangerous results, the presence of a considerable quantity of lime in the material, acting as a cement, binds this together with a firmness which would hardly be expected. In general, in all such slopes [illegible] your text-books or lectures have doubtless informed you the [illegible] maximum or critical angle of slope which must not [illegible] as in the instances mentioned, much will depend [illegible] *nature* of the material, rough angular blocks hav[illegible] slide over each other than would be the case with [illegible] hillside containing much clayey material would by [illegible] water and by becoming softened thereby be much more likely slide than one which is sandy, and therefore relatively [illegible]

I may notice is passing that these differences also apply to the *excavations* which have to be made through masses of loose material as cuttings. The readiness with which the latter is removed by torrential rains suggests the use [illegible] streams of water, driven by steam, (as in hydraulic mining) as a means of effecting [illegible] cheap method of removal [illegible] which, in the construction of I. C. R. was largely used along the Metapedia valley.

[illegible] may also remark as incidental to this branch of the subject, that the necessity of crossing swamps and bogs sometimes introduces difficulties of a peculiar kind, also connected with geological phenomena. The bogs are often covered to a considerable depth with a growth of sphagnous moss, firm enough it may be to support the weight of a man or even of a horse but not sufficiently strong to [illegible] the weight of [illegible] and it is said that more than one [illegible] was lost in attempting to [illegible] some such bogs not far from [illegible] at the time of the construction of the railway there. On [illegible] hand in the [illegible] Lake near St. John, the difficulty of crossing this [illegible] the vast quantity of material [illegible] to accomplish [illegible] for [illegible] time to the belief that the lake had no bottom [illegible] that the materials [illegible] by the giving way of the soft [illegible] bottom [illegible] they were being piled. This soft ooze is frequently [illegible] Infusorial Earth which has accumulated [illegible] when what is now a bog was a pond or lake, and, [illegible] coherence, it forms but a poor foundation upon which to build.

[illegible] other kind of material with which the railway [illegible] may, in our northern latitude will be almost sure to co[illegible] is the [illegible] Boulder clay, the material left scattered [illegible] the surface [illegible] the retreat of the great continental gla[illegible] which [illegible] of North America was at one time deeply [illegible] As its [illegible] indicates, it is a clay deposit through which are scattered promiscuously rock boulders of every variety of size and character. [illegible] clay is usually very tenacious, and therefore difficult to remove; impervious and therefore not easily drained; if it contains much [illegible]es, either in the clay itself or in the boulders, the decomposition [illegible] matter is apt to give rise to ferric hydrates, which further compact the material, determining what is known as "hard pan" and which is [illegible] hard as to be difficultly penetrable even with a pick. A good example of this boulder clay was exposed in making the foundations of the Engineering Building, as it was in those of the main University building, and in each case proved a somewhat difficult and costly material to remove.

From comparatively loose materials we come now to consider circumstances in which the railway engineer has to deal with solid rock. This will be the case in all rock cuttings, whether due to the crossing of low ridges, where the road skirts the sides of abrupt hills, or finally where tunnels have to be driven through the latter. In each of these cases it is neccesary, in calculations of cost, to consider (1) the relative hardness of the rock, (2) its structure whether massive or bedded or jointed, and (3) if bedded, whether the stratification be horizontal inclined or folded.

As regards *hardness*, rocks which are crystatlline, like granite, syenite or trap, are as a rule much harder than those which are non-crystaliine, like sandstones and limestones. Conglomerates also are usually hard because their pebbles are so, while shales are sometimes so soft that they may easily be removed with the pick. Rock containing much hornblende, an iron-bearing mineral, are especially apt to be very hard and tough.

As regards *structure* we find that even the massive rocks are intersected by joint planes, and as the ordinary quarryman finds them very useful in guiding his operations, showing the lines of weakest cohesion, so the railway engineer who has to penetrate rocks of this character would find it of advantage to recognize their presence and direction. In the case of slates the number of divisional planes is much greater and act in the same way as joints, but the engineer, like the geologist, needs to be able to distinguish between such slaty cleavage and true stratification, as otherwise he may be led into very serious error as regard the thickness or continuity of the beds through which he proposes to pass. In the care of rocks which are stratified it may again make a great deal of difference whether the line of section is coincident with the trend or strike of the rocks, or whether it be with or against their dip. Probably these points do not often enter into the calculations of the engineer, but as a non-professional man I am alluding to what, in the eye of the geologist, would seem to be important factors.

In connection with the subject of railways comes in not merely the removal of opposing ridges, as by cutting or tunneling, but also the filling of depressions, and in general the construction of the road-bed. Not all materials answer equally well for such a purpose; for they have different degrees of cohesion, have different critical angles of slope, have different capacities for supporting the growth of vegetables such as grass, and above all are differently affected by frost. The best material for deep fillings would of course be large angular fragments of rock, such as near-by cuttings often afford; the worst would be the burial of fallen trees by gravel or sand, such as was the case with some very heavy fillings near Newburgh in the earlier days of that branch of the C. P. R. As far as frost is concerned, course granite gravel is probably next to cinders, the best material to use, as being least affected; the worst materials are those containing much clay, as holding water tenaciously, besides being so light as to be swept away even by small streamlets.

The protective agency of vegetation in connection with the permanency of land in general is an important subject for the engineer. A bank well covered with grass and bushes is much less likely to be gullied out than one not so protected. In Queens and Sunbury counties great damage was in former years determined by the fact that the formation of waves by passing steamers caused the undermining not only of the roads near the banks but of large quantities of valuable land, and large sums of money were expended by the goverment in the driving of rows of piles along exposed places. A much more effective remedy is the natural growth of willows, which like the Mangroves of tropical countries, seem specially adapted by the number of their roots and stems not only to protect but to make land.

Again, forests on mountain sides hold the snow and check the descent of avalanches,and for this reason are in Switzerland protected with great care.

I may now observe that many of the facts which have been referred to in connection with railways, apply also to *ordinary highways.* These are subject of course to much more numerous and abrupt changes of profile, and the gradients are often much steeper; but the proper location of a road is a matter which should not be lightly dismissed and one has only to travel extensively, as I have, the highways and by-ways of the Maritime Provinces to see what a vast amount of energy might have been saved had these thorough-fares in the first instance been placed where they should have been. Indeed it would seem that in laying them out, in the early settlement of the country, the plan was very generally followed of going to the top of each hill, and thence taking the shortest possible course to the summit of the next. The fact that in the case of many if not most hills, the distance around their base is no greater than over the arc of their curvature was seldom recognized; while the supposed necessity of making the roads correspond exactly to the base line of lots, helped to make the choice of location still worse.

But apart from the question of *location*, in the case of highways, comes in the far more important one of *construction* and *materials*: and here again there is the widest range of possibility from the corduroy of the southern swamps, humorously described by Olivir Wendell Holmes as consisting of "first log, then alligator" up to the compact, smooth and durable driveways of the New York or Boston suburban parks. It would not be in place here to describe the methods of construction employed in these latter cases, but a few words as to the materials employed may not be inappropriate.

These materials fall naturally into two divisions, viz. (1) Those which, already more or less comminuted, are directly available as turned up by a plough or road machine, and (2) those which, as in all forms of macadamizing require to be broken up before application. As the former is all that is ordinarily available it is that which gives character to our country roads, which will be rough and stony or soft and rutty just according as loose rocks or clay predominate in the materials employed, and as the attention bestowed upon them is much or little. In and about towns and cities, especially where there is heavy wear, harder and more enduring materials are imperatively required. But hardness is not the only necessary quality. There needs to be *uniformity* of hardness and in addition to this, what may be termed "binding power." These differences are well illustrated in the results of the careful trials made by the Massachusetts Road Commission on various kinds of road metal. Thus granite is regarded usually as a *hard* rock, but it is poor material for macadamizing, because it is not homogeneous, being made up of three different minerals, —quartz, felspar and mica— of which the former being the harder, serves to quickly grind down the latter. Sandstone is composed of quartz only, but most sandstones crumble readily, and the resulting material has little cohesion. Limestone again is homogeneous, but is very soft, has no lasting qualites, and is soon converted into a fine dust which is very irritating. By far the best material is the rock known as basalt or diabase, a firm, black, finely crystalline and very homogeneous rock, of volcanic origin, which in addition to a considerable degree of hardness possesses remarkable binding power, and thus, like artificial cinders, goes to form a road bed which is at once firm, compact, smooth and enduring. In this Province such rock is to be found at many localities, such as Currie's Mountain in the vicinity of Fredericton, Boiestown, Long Island in Queens, and in many parts of Charlotte, King's, Victoria and Restigouche counties. It is now being used to some extent in St. John, in preference to the limestone and slate formerly employed, being obtained in the neighborhood of the Reformatory, but the fact that in that city all excavations and gradings are in solid rock which *has* to be removed, has caused the cheapness of these materials as compared with others brought from a distance, to outweigh all other considerations. In Fredericton considerable quantities of the Currie's Mountain diabace are used, but until recently mostly as a sort of top-finish, motives of economy still leading to the association with the latter of the very inferior coal-measure sandstones. At present, I believe, the disposition is to use the trap-rock throughout, but as yet the best quality of the latter has not been obtained.

From railways and highways one passes naturally to *Canals*, and it is almost needless to remind you that in connection with the latter are some of the greatest engineering achievements which the world has known, as witness the Suez Canal and those, not yet completed, by which it is proposed to make a waterway across the Isthmus connecting North and South America.

Canals may be constructed for a variety of purposes; as for navigation, for irrigation or for purposes of water supply and drainage. In each case the conditions are in a general way similar to those referred to in connection with railway construction, and geological facts and principles need equally to be taken into consideration. The work is largely one of excavation, and the materials to be excavated again vary in nature, arrangement and structural peculiarities. Where intended as an aid to navigation, they either connect existing sheets of water or are designed to overcome by means of locks difficulties arising from the presence of rapids, falls or other obstructions. Hence their location and construction involve a careful anterior consideration of all the facts connected with the natural drainage of the district in which they are to be placed. Still more is this the case where the canal or canals are designed for purposes of irrigation and water supply. Here the engineer has to consider the conditions of climate and of rain fall, the extent of the catch-basin from which he proposes to draw his supplies, the geological conditions incidental to the existence and permanency of springs, the possible sources of mineral and organic contamination, the amount and rapidity of sedimentation, the most favourable sites for dams and flumes, the periodical variations of pressure, and the capacity of the sides or walls or conduits, whether of wood, earth or stone, to withstand the pressure. The enormous interests involved in this subject and the varied conditions, largely of a geological nature, which have to be taken into account, are indicated by the effect of the great dam at Assouan, on the Nile, only recently completed, and the irrigation systems, which, with the assistance of the national government, are now being contracted in the arid regions of Nevada, Colorado, Montana and Arizona.

Out of a total of 610,000,000 acres of land lying west of the 100th meridian in the United States and possessed of a fertile, arable soil, but lacking sufficient moisture to be of service for agriculture, only 3,631,381 acres, or less than six-tenths of one per cent. have as yet been provided with a water-supply sufficient to ensure the maintenance of crops. Of course the supply itself, derived from the high mountains and carried often for long distances, is not adequate for the needs of all the vast tract, but taking the whole amount of water available in the arid region to be 360,000 second feet, or 360,000 feet per second, and the average water-duty 100 acres to the second foot, the total irrigable area is about 36,000,000 acres, or about ten times that which had been brought under successful irrigation in the year 1890. The volume of the Thirteenth Annual Report of the United States Survey now upon the table, will illustrate the extent of this great system of artificial canals, and the very various conditions as regards the materials traversed, whether solid rocks or shifting sands, under which they have been constructed, the construction of the flumes, weirs, head-works, regulator gates, reservoirs, etc., etc.

The subject of Artesian wells is naturally suggested in this connection a and right understanding of the conditions upon which their successful operation depends, conditions which are largely of a geological nature, is very essential to the equipment of a well-informed engineer. First recognized in the district of Artois in France, they are well exemplified in the valley of the St John river at Fredericton, and in view of the complaints so frequently heard as to the character of our drinking water, as derived from the river, it is a pity that more serious and more intelligent attempts were not made, at the time of the introduction of our water system, to obtain from deep subterraneous sources the supply which no doubt exists there, and which for purity and freshness could not have been excelled.

The sketch now upon the wall will make clear the grounds upon which this opinion is based. It represents a section of the river valley across its entire extent. I have spoken of Canals, but *Rivers* are natural canals and there are a great many subjects in connection with the latter which well deserve the engineer's attention.

Among these may be included the volume of rivers ; the periodical change of volume with changing seasons ; the varying velocity at different times ; the influence of lakes as tending to determine uniformity of flow as well as the removal of sediment ; the tendency of streams to oscillate, right and left, like a pendulum, determining meanders ; the formation of bars and islands ; the silting up of harbours at their mouths ; the possible improvements of navigation by removal of obstructions or deepening of bed, or formation of locks. The drainage of lakes,like that of Haarlem, in Holland, the building and maintenance of dykes, levees and aboideaux like those of the Mississippi, or the construction of jettees such as exist at the mouth of the last named stream are also subjects often of a stupendous character and calling for extended knowledge upon the part of the engineer, not merely as regards the use of materials and the cost of construction, but as regards also all the characteristics of river currents, tidal currents, wave action, sedimentation, hydrostatic pressure which so largely determine the efficiency of such works and their permanency.

I may here observe that the whole subject of the relation of Topography to Geology is an interesting one and of much practical value to the engineer. The geologist makes use of this relationship in order to obtain at a glance some idea of the probable structure of a region which he is about to examine in detail. He can foretell, even at a distance, from the surface features, the relative distribution of hard and soft rocks ; he can distinguish granitic hills from those of aqueous or igneous origin ; he can infer the general directions in which rocks run, and parallel with which will probably be found the main lines of fracture and dislocation. So the engineer, if he understands these relations, can draw similar conclusions, and thus looking over a region from the summit of some eminence, be able to draw very valuable conclusions as to the difficulties to be met with in traversing it, and in the choice of location.

In mining especially is this relation of topography to structure all important; and one of the standard works upon the subject of coal-mining, more particularly as exemplified in the coal-fields of Pennsylvania—is Leslie's Coal and Its Topography, in which the connection referred to is very fully worked out.

In these Provinces the broad rounded hills of the Nerepis valley, composed of granite; the sharp conical Peak of Teneriffe on the Nepisiquit, composed of felsite; the vertical bluffs of trap on the Royal Road near Fredericton or along the northern side of Grand Manan; the valley of the St. John, broad and open, with numerous islands, where it traverses the central coal-field of soft and horizontal strata, narrow and deep where it passes through granite or tilted slates: are all illustrations of the relationship to which I have referred. The Palisades of the Hudson, the Organ Mountains of Brazil, Table Mountain at the Cape, the Cathedral rocks of the Yosemite valley, the Sugar Loaf near Campbellton, N. B., further illustrate the same subject.

From the subject of the greater engineer problems—such as the construction of lines of railway, canals, aqueducts, and systems of irrigation, we may now pass to consider for a few moments the relations of Geology to Architecture.

Here two points are mainly to be considered, viz (1) strength of materials, and (2) durability.

With regard to the former numerous experiments have been made, relating to the power of rocks to withstand on the one hand a crushing force or that of mere weight, and on the other a transverse strain or sheering stress, and doubtless the results of these experiments are to be found in ordinary engineering manuals. But there are some points connected with this subject which are not so commonly presented. One of them is implied in what has been termed the "flow of rocks" and has reference to the fact that under long sustained and powerful pressure, rocks exhibit a degree of plasticity in virtue of which they will slowly alter their form and probably their consistency, and may even be made to acquire in some degree the properties of a fluid. This fact was long suspected from the study of arched and corrugated strata, where materials ordinarily brittle have been bent like sheets of paper, or from an examination of certain conglomerates, of which the enclosed pebbles have cordently been elongated as well as twisted: but it was not until the recent experiments upon the subject in the physical laboratories at McGill had been made, that the fact of the possibility of such change was fully appreciated. The bearing of such facts upon the construction of buildings and structures generally in which great weights have be sustained will of course be obvious.

A second feature of interest is the existence in nearly all rocks of what may be termed "the concretionary structure," a structure in virtue of which apparently homogeneous rocks will, especially under the influence of intense heat, separate in concentric shells. This was well exhibited at the time of the great conflagration at St. John in the case of the granite blocks forming the foundations of the old Victoria school and which, though in their original shape square or rectangular, became by the action of the fire completely rounded, so as to look like piles of cannon balls. Similarly at the time of the big fire in Boston it is stated that from the face of the great granite blocks exposed to the heat, great rounded sheets peeled off, much like the coats of an onion. The same result is sometimes brought out, and upon an enormous scale, as the result of weathering as in the case of the Yosemite valley in California, where such prominences as the North Dome, Half-Dome, etc., owe their rounded forms to similar causes.

This reference to "weathering" leads me next to speak of the *durability* of rocks, or rather to the *decay* of rocks. Such decay is common to all rocks, and is the means by which in a large degree they are broken up and converted into *soil*. But the rapidity of the process differs greatly in different rocks, and has a marked bearing upon the suitability of these for construction or ornamental purposes.

Disintegratsion may be due to two causes, one mechanical, the other chemical. In the first place porous rocks readily absorb moisture, and if the climate be one subject to considerable reduction of temperature, this moisture in the winter season will freeze. But frozen water occupies more space than liquid water, and hence in freezing expands. It does so moreover with almost irresistible force, as illustrated by the heaving of tracks, the over throw of fences etc. and where such effects take place between the grains composing masses of rocks the results are considerable. Obviously such rocks as sandstones or freestones will take in much more moisture than granite, especially if the latter be polished, and one has only to compare in an ordinary grave yard the tomb-stones composed of these two materials and also those of marble, to see how marked are the differences between them. In the case of limestone or or marble there is the additional fact that the material composing it is to some extent soluble in water, thus further promoting the rapidity of its decay. Different kinds of rocks seem also to be unequally suited for the growth of mosses, lichens and fungi, and where these find a congenial basis on which to grow, the decay of the supporting rock is much more rapid than where the surface remains clean and uncovered.

This leads me to the second of the two classes of effects to which I have referred, viz., the chemical one. Few rocks are wholly proof against chemical change. Pure water, it is true, does not make much impression upon them, but natural waters are always carbonated, and carbonic acid or carbon dioxide is a very effective agent in bringing about new chemical combinations. It dissolves carbonate of lime directly as in the case of limestones and marbles referred to a few moments ago; while in the case of rocks containing felspar, such as granite, syenite or porphyry, it attacks the alkali of the latter, and thus determines a rapid disintegration. This is the main cause of the difference in color and hardness between the inner and outer portions of rocks of this nature, or in case of granite between what is termed rotten rock and that freshly removed from the quarry.

A person may wholly mistake the nature of a rock as to hardness and the consequent cost of removal from regarding the outer surface as representative of the interior. Rocks sometimes weather in for half an inch or more while the weathered portion may be quite soft, the interior remaining such as to ring under the hammer, e. g Chamcook Mountain.

But even tho' the rock as a whole may, as in the case of freestone, be little liable to attack, it may contain scattered through it, in greater or less quantity, materials which are very susceptible to chemical change. The most important of these is pyrite or iron pyrites, a compound of iron and sulphur, of a yellow colour, and sometimes known as mundic, sometimes as fools' gold. There are few rocks entirely free from pyrites,and as seen in freshly quarried rocks, where it is found in scattered crystals or small nodules, it does not seem as though its presence was a matter of any consequence. But let a block or pillar containing one of these nodules be exposed to the air and we soon become aware of its injurious effects. First there is seen a brown rusty-looking spot, which gradually enlarges. Then a long tongue, similarly discolored, is seen running down the face of the building, it may be for several feet or yards ; while at the same time at the starting point of the process not only does the colour deepen, but the rock begins to crumble, and soon a hole appears which in time may attain the dimensions of several inches. Such changes tend greatly to the disfigurement of the rock or edifice in which they take place. Very good examples are to be seen in the sandstone pillars of the University Building, especially at its northern end ; and again in the Cathedral. In the case of the Post Office building it was found necessary to remove an entire block of stone from near the entrance owing to the unsightly appearance thus determined.

The subject of *Sanitary* Engineering as related to Geology is one deserving a brief notice.

The Health of communities, large or small, is often one of vital importance, and requiring the expenditure of large sums of money. It involves the question of water supply, both as to quantity and quality; the calculation of drainage area, their relation to rainfall , the construction of tanks and reservoirs, with the capacity and strength of the latter : the relative purity of natural waters, whether derived from surface wells, springs, (soft or hard), lakes (as bordered by or free from the effects of peat-logs ; or from rivers as influenced by the presence of forests, settlements or towns along their banks, with possible contamination from cultivated fields, sewage systems, and waste products of gas, acetylene, dye-stuff or other factories It involves also a consideration of the nature of strata, whether horizontal or inclined, as determining the flow of underground waters and sewage, and the part played by different soils as natural filters ordinary sand being far more effective than any artificial expedient These are but a few of the many directions in which the Engineer may be called upon to promote public health, and which depends for more successful issue upon a knowledge of geological facts.

I now propose to say a few words upon a subject widely different from those which I have been considering, and yet one where, even more than in any of the instances previously alluded to, the Geologist and the Engineer meet on common ground. I refer to the subject of Mining, a branch of such importance that many engineers devote themselves to it alone.

It will be readily understood that all that I have before said with reference to rock removal applies here. Shafting and tunneling are the main processes by which the treasures of the earth are reached and brought to the surface, and the same attention has to be paid, where these are designed for mining purposes, to the varying nature, structure and position of rocks, as where the excavations are for purposes of transit. But there are many points in connection with the successful operations of mines which are of little consequence in ordinary railway or highway work. For the object to be attained is different. In railway cuttings and tunnels the object is to get a suitable passage by the direct route; in mining the object is to find useful minerals and to remove them at the least possible cost. And, before attempting this at all, certain geological facts need to be carefully considered.

For instance the material sought may be coal or iron or the ores of the rarer metals, and the conditions of occurrence of these are by no means the same. Coal is found in beds, iron ores both in beds and veins; most other ores in veins only. But beds and veins are very different things, different not only in their origin, but in their mode of occurrence and in the methods of their treatment. Beds are, as the name implies, strata, the results of sedimentation, and therefore lie parallel to and have shared in all the movements by which the associated strata have been affected. They have regular courses and regular dips or inclinations, and from the study of these it is easy to form an estimate of their extent, their position below the surface at any one point, the productive capacity of the basins of which they form a part. Veins on the other hand are rarely the result of mere sedimentation. They are the fillings of fissures, and these like other cracks follow no well defined law. Occassionally, as in what are known as bedded leads, common in the gold districts of Nova Scotia, they may lie like sheets, between enclosing strata, following them for considerable distances; but far more commonly they are what are known as "fissure veins," the filling, that is to say, of irregular crevices or cracks which intersect the beds, and show little or no relation to the character or position of the latter. Hence in the case of a bed of coal or a bed of hematite the thickness which it presents at any one point is likely to be retained for a considerable distance both along the surface and in depth; and the productive capacity of a coal-area may be estimated with great accuracy; veins on the other hand are subject to constant and extreme variations, making it impossible to fortell how far they may be depended on, and even where their thickness remains unaltered, they may undergo frequent changes as to their nature and mineral contents.

I will next notice the necessity, upon the part of the mining engineer, of having some knowledge of the subject of faults or dislocations. These are specially important in connection with coal-mines and the frequency of such faults or jogs in the coal rocks skirting the head of the Bay of Fundy is indicated in the well known name of the Joggins. Such dislocations may be to the extent of a few inches only or less, or they may amount to thousands of feet, strata which were at one time continuous becoming thus separated to a corresponding distance. In portions of the Rocky Mountains faults of 40,000 feet or nearly eight miles, have been observed, and much of the peculiar topography of that range and the grandeur of its constituent ranges has been determined by the great slips whereby the crust of the earth has been affected in the efforts of the latter to accommodate itself to its shrinking interior. In ordinary metal-mining these great faults or cracks are of interest as the repository of mineral veins, witness the Comstock Lode in Nevada, from which in less than fifteen years 360 millions of dollars were obtained; in coal mining they are important for the reason that they break the continuity of beds and at once make it necessary to determine the amount and nature of the dislocation, *i. e.* whether it be an up-throw or down-throw and the distance by which the two portions of the broken bed are now separated Though no invariable rule can be given it is well to remember that in most instances the fault bodes towards the down throw, in other words the plane of dislocation slopes toward the bed which, relatively to the other, has been dropped.

A knowledge of the materials constituting veins is important. As these are the fillings of fissures, and the filling material has in most instances been derived, through pressure and heat, from the bounding rocks, there will naturally be some relationship between the two. Thus where the rocks are silicious, such as sandstones or quartz, etc., as in most gold districts, the veins are of quartz; if the country rock is limestones, as in many regions of lead and zinc ores, the veins are commonly composed of calcite or barite. There are also definite laws of association, as in the case of fluor, often called the "mother of lead" into which I cannot now enter; but this point at least it may be well to remember, especially in prospecting for gold, that well mineralized veins or lodes, *i. e.* those carrying an abundance of metallic sulphides, such as pyrites, mispickel, galenite, etc., are much more likely to carry also the precial metal than those which are composed of quartz only. Perhaps I should add that all is not gold that glitters; but it is equally important to remember that very high value may be contained in in materials which show no outward indication of it. Thus the cobalt and nickel ores of Saxony were as first regarded and rejected as worthless, their names having reference to the idea, entertained by the superstitious miners, that they had been the sport of the spirits of the mines. Similarly in western Australia large quantities of tellurics of gold, an earthy looking compound, was for some time after the first opening of the mines in that region, discarded as of no value, though it is from this same despised material that the larger part of the total yield of gold is now obtained. One who is going into the business of mining engineering cannot have too thorough a knowledge of mineralogy as well as of structural geology.

The methods of mining call for the highest skill of the engineer. For he must not only sink shafts and run levels, but he must do this with constant knowledge of the relations of these to each other and to the position of ore-bodies. He must construct plans of all underground workings and know exactly the cost per yard of their excavation. He must have contantly in mind the enormous pressures present in the earth's crust,and be prepared, by proper systems of timbering, to withstand the thrusts thus determined. In deserted galleries of the old Albert mines, in New Brunswick, after only a single year's disuse, I have seen the great props which sustained the gallery roofs, though nearly two feet in diameter and set closely together, bent inward like hoops, as the result of the enormous downward and lateral pressure which was weighing upon them. Then the engineer must understand the principles of ventilation, for men cannot work in vitiated air, and the accumulation of gases, resulting not only from the respiration of the miners, the burning of their lamps and the conbustion of explosives, but those originating like fire-damp, by natural process in the mine itself, introduce elements of danger which must be anticipated and provided for. And then there is the ever-present difficulty of water.

Not in every mine is this so formidable an obstacle as in the case of the great Comstock Lode, in Nevada, to which I have already referred, from which by the construction of the famous Sutro Tunnel, an excavation four miles long and costing over two millions of dollars, water was discharged at the rate of nearly 4,000,000 gallons per day ; nor is the subterranean water always or generally at so high a temperature as this, viz. from 120 to 137° Fah. but there are few mines in which the influx of water is not a serious obstacle, and one with which the highest capacity of the engineer has to deal. Even after the construction of the Sutro Tunnel, it was necessary to lift water from the deeper levels to the point of discharge, and numerous engines, capable of raising in some instances as much as 800 gallons per minute, were employed, the enormous sum of 20,000 tons of water being raised in a single year to the level of the tunnel's mouth.

The effects of these underground waters are sometimes very curious. I have here for instance two specimens whose external form at once suggests the [illegible] they are a portion of tracks or tramways, along which heavy [illegible] must have been transported. Originally their own weight [illegible] been considerable, but let me ask you to handle them and [illegible] your estimate is justified.

Nor is it merely the presence of water in the mines and its conequent interference with work which give trouble to the engineer. Such water is liable to originate chemical change either in the ore or in the country-rock or in both. This may lead in the latter case to the softening and crumbling of the walls, as when felspar decomposes into a soft clay, [illegible] it may result in the determination of much heat. I have already alluded to the temperature of the water in the Comstock Lode, but what about the air resting upon this water and charged with its vapour? We all know how hard it is to endure a temperature of 85° or 90°, especially if the humidity be high or the air, as we term it, [illegible], and that too even when we are making no physical exertion. Imagine then the condition of miners, undertaking the very hardest kind of labour, at a level 1100 feet below the surface of the earth, with a temperature ranging from 100° to 130° F. and in narrow galleries from the sides of which streamed water which was hot enough to scald. No wonder that where picks could only be handled with gloves, where rags soaked in ice-water had to be wrapped around iron drills, where work had to be carried on in successive relays, sometimes lasting for only a few minutes at a time, where pools of water often lined the galleries so hot, that the human body, if dropped therein, instantly became parboiled; where tons of ice had to be daily sent down into the mines, each miner it is said consuming 95 lbs. every day; where finally not less than 40,000 cubic feet of air per minute had to be forced into the mines to make any respiration possible,—an amount abstracting in connection with the efflux of water, as much heat yearly as would be yielded by the combustion of over 60,000 tons of anthracite—; no wonder I say, when such facts as these are considered, one finds it hard to understand how work is carried on at all, or how human beings can be found who are willing to undertake it. But high wages and the thirst for gold are sufficient to over-ride all other considerations, whether these arise, as in the case of the Comstock Lode, from the attempt to obtain treasure from what are practically the furnaces of an old volcano, or on the other from the frozen gravels of a Klondyke, access to which, during the first year or two of its discovery, again necessitated physical dangers and endurance which are well nigh incredible.

And wherever such work is undertaken, and whatever the trials and hardships involved, then the engieer must go and take his part in the struggle. He must lead the way; he must see what the essential difficulties are and how they can best be surmounted; upon his judgement, foresight, bravery and persistence rest the issues of success or failure.

And now, my young friends of the Engineering School, I trust that in what I have been able to say to you this evening, I have also been able to contribute, if only to some small degree, towards your attainment of success in your chosen profession

From what I have said it will appear that the life of the Engineer—especially of the Civil and Mining Engineer— is by no means an easy one It is a life of hardship and exposure not unmixed with danger. It is a life of responsibility wherein are required careful forethougnt, accurate knowledge of materials and conditions, power of endurance, patience, determination. Like the geologist, the engineer is brought face to face with nature—not merely with dead nature as seen in the crust of the earth over or through which he has to lay his rails, drive his tunnels, construct his aqueducts, or sink his mining shafts and galleries, but nature also in action, as seen in floods and cataracts, in land slides and avalanches, in tornadoes and cyclones, in the presence of natural and artificial explosives, but in proportion as he understands nature in all her various aspects will he be able to get the best results in any work he may undertake ; just so far as he takes heed to nature's laws will his work possess the essential elements of thorough efficiency and permanency.

I feel sure, gentlemen of the Engineering School, that the course which you are following in connection with this University, is one which will ensure, in a high degree, the qualities to which I have referred. I have only, in conclusion, to wish you, one and all, unqualified success, not only in your preparatory studies here, but in your life work.

Railway Construction.

By P. W. Holt, C. E.

FEBRUARY 19TH, 1904.

HAVING been asked by Prof. Brydone-Jack to give a little talk on the subject of Railway Construction I will begin by assuming that the location has been made and we are ready to begin the actual work of building the railway. In doing this we will take first the draftsman's privilege, when he builds in paper, of beginning at the top and putting the foundation under afterwards to suit the superstruction.

We will assume that the class of road which we are to build has already been fixed. This determines the grades, curves and the kind of materials which will be used in its construction, and must be put in such shape that the contractors, who will do the actual work, may know just what they are expected to do.

That is to say we must write a specification setting forth just what is wanted. Just here is one of the most important parts of the whole work. If the specification is clear and definite, showing that the engineer knows what he wants and is not given to quibbling, and is ready to meet a contractor fairly, the personal element of the engineer will result in getting good contractors and the work will be done for just about a fair business profit above the actual cost of doing the work If the specification shows that the engineer is guessing and is uncertain about parts of it, but is very insistent upon some one idea or ideas, that is, has fads or quibbles, the best contractors will bid high to protect themselves and the poor ones, and perhaps tricky ones, will bid to take the work taking chances to come out right or squirm out somehow.

A large part of a constructional engineer's duties, outside of the mathematical part, is to act as a referee or arbitrator between the Company or employer on the one part and the Contractor on the other. That is to say; true economy requires that the engineer shall be definite, honorable and just, and he should know good work from poor and whether a contractor is handling his work right or wrong, and whether he can do the work for the sum offered or not. We have the authority of Holy Writ that "The laborer is worthy of his hire" and any man who undertakes to do a thing for less than it is worth, unless as a deed of charity -and contractors do not work on a railway with this object in view,— is going to come out even some how and somebody has got to make up the loss. Of course good men make mistakes at times, and suffer loss through misjudging elements of the work, through no fault of the engineers, but as a rule, it is just as much of a mistake in the engineers part, and against the interests of the Company which he represents, to let work too low as it is to err the other way and let it too high.

We will now assume that the specification has been written and the work fully and carefully described.

There are two ways of letting a contract, first by a lump sum or at so much per mile for a number of miles—it may be the grading or the completed road. Second by certain units at so much per unit. These units are usually the acre or square rod for clearing or grubbing, the cubic yard for removing earth or rock and masonry of all kind,—though sometimes masonry is measured by the cubic foot,—the foot board measure or the lineal foot for timber work and piling, or by the piece for piles, caps, etc., iron by the pound and special prices for special work, as tile drains by the rod or foot, fence by the rod. Crushed rock or rock to be crushed by the ton, cubic yard, cord, or if in the Province of Quebec, or near it, the trois of three feet by six feet by twelve feet or eight cubic yards

To let by the second method is really fairest to the company and the contractor, as it gives the Company an opportunity to build in the best manner, as the work developes, without inflicting hardships on the contractor, or subjecting the company to a bill of extras, as he is paid by the quantities that go into the work at a predetermined price per unit. This seems simple, and is; there should be no trouble if all of the facts are understood before hand and both engineer and contractor are desirous of fair treatment, but sometimes, through no fault of the engineer or the contractor, work turns out different from what was expected simply because money was not provided to sink test pits and no one knew what the subsoil was—it was only guessed at—and some one has to pay for the missguess.

Here let me interpolate a remark that applies to all branches of the engineering profession. We have to deal with the laws of nature, which are inflexible No one can be violated without paying the penalty. If we undertake to guess, and guess wrong, we get our punishment immediately upon the completion of the act, if permitted to complete it, but, with our present facilities for acquiring information, there is no excuse for guessing in most cases and this is why you who are students here—and we all have to be students through our professional life—are principally engaged in the study of natural laws and learning how to measure and value them in terms by which we can comprehend them.

The usual and most common units are first—Cleaning; this means the removal of all foreign perishable material from the right of way, to such a width as shall have been specified—generally four rods or one hundred feet as has been fixed before hand. The material to be removed is usually trees, standing or fallen, and bushes. It is usual and best to remove all material that will decay under embankments, such as trees, bushes and logs, but there are cases where it is best to leave some of the trees standing, as in a side hill to keep the bank from sliding till it becomes incorporated with the soil itself cutting them off well below subgrade; also where an embankment is subjected to freshets from streams overflowing their banks, bushes help to retain the embankment until it becomes united with the soil beneath it.

This clearing should be done neatly, material of any value saved, and the rest piled away from the adjoining forest and burned with care not to endanger the rest of the forest. One of the most desolate scenes along a railway is the forest burnt on either side caused many times by the carelessness of the men who were cleaning the right of way. The trouble lies in that the first fire may only kill the growth, which possibly might be replaced by a new growth in a comparatively short time if the killed trees were removed—but they are not, and at the first dry spell become food for a second fire, that, in a rocky country only fit to grow trees, burns up not only these trees, but also the vegetable matter in the soil which would have nourished another growth, and we have left only a barren track that may remain for years to come,—all because some careless, selfish, thoughtless fellow did not take care of his fires when he was clearing the right of way. I have in mind now a tract of land in Charlotte County that was burned over in this way in 1876, nearly 28 years ago, that has only a scattering growth of bushes now, where then it was crossed with a young forest which would now be yielding logs. Instead it is practically only a barren, nearly naked and unsightly. We cannot pay too much attention to the appearance of the right of way and its surroundings. One has only to be taken away from our New Brunswick woods and among their growth and surroundings to appreciate their beauty and to feel that it is almost criminal to wantonly destroy them. The area of this spruce and fir is only small compared with the rest of the continent.

The height at which trees should be cut is largely a matter of convenience, only under banks they must be cut short enough not to come near the sub-grade line where the embankment has settled. The stumps will become loose in a few years and can then be removed and the right of way cleaned. One trouble when the forests were large, in the past, was that trees might blow down and reach across the track and endanger a train. If there are any such trees they should be removed, but they are generally good timber and usually the owner will attend to that.

Grubbing : — Next to clearing comes grubbing. This means that in such places where the grade and the surface of the ground came within a fixed distance of each other, commonly two feet, that the stumps and roots of the trees that grew in this section, must be removed ; that as a matter of fact in this space, the cost of removing this body of earth, bound together as it is with roots, is so much greater than when the earth to be removed is deeper, that the contractor is not compensated for his work by cubic yard payment, he is therefore usually paid by the square rod or acre for the area included between the slope-stakes or any area that the Company may wish cleared of roots and stumps as culvert foundations, etc., etc.

Earth : — This term covers a great many varietes of materials, but it is in large contracts all classed under the one head, until it becomes so hard and tough that four horses and a plow cannot break it, when it becomes hard-pan. This material has to be seen and worked to be appreciated. It is a tough semi-elastic deposit, composed of stones and earth generally, almost cemented together, but yet softer than rock. It has a habit of resting under an innocent looking sandy or loamy soil, so completely concealed as to be unsus pected unless long experience has taught one to expect it or at least be suspicious of its presence; a test pit would have disclosed its presence, but the pit was not sunk. This material has been the cause of much litigation between contractors and companies, and should be provided for, if suspected in the section or, either the contractor will protect himself by asking a higher price per cubic yard, for all of the earth work, or else lose money by ignorance of its existence and be practically robbed if not paid for it extra, or may have a cause of action against the company which will cost more than to have provided for it in the first place. In either case ignorance is expensive, and, as a rule, the Company, which is generally the employer of the engineer, is the party which has to stand the loss, as is right.

LOOSE ROCK:—In some earth banks there are rocks so large that they cannot be removed without breaking or fitting up a special rig for the purpose, this interferes with the routine of filling carts or other means of mining earth, and it is usual to have a price per cubic yard for all rocks of this size that are not large enough for solid rock and too large to be handled by a span of horses and a stone boat or drag, without breaking up; this is usually one half cubic yard or more. The usual system of measuring these rocks is to average them, by the eye, into a length, breadth and thickness that will produce a parallelapipidon of equivalent cubic contents, a matter that becomes easy with practice.

SOLID ROCK:— This generally means rock in place or ledge and is of all degrees of hardness and ease of removal. About as difficult piece of rock as can be found is a tough slaty rock with the laminations nearly vertical and the axis of the cut and the strike of the [illegible] parallel or [illegible].

Earth and rock of their several classes make up the bulk of the embankments and their removal makes the cuts. All of the earth from the cuts does not always go to the embankments nor are all of the embankments made from the cuts. The earth and rock should be measured in place, that is before it has been disturbed from its natural position, as earth that has been handled may occupy more or less space than originally, depending upon how it is handled, and, as the object of these measurements is to pay the contractor for the work which he honestly does, the only fair way is to pay him for the earth which he removes from its natural place, except that there may be conditions in which he may not be paid for wasting under fixed terms of the contract, but in any case the adjustment should be made on the basis of earth in place.

Masonry: — Under this head comes a variety of work, and it might almost be called natural and artificial stone work. The roughest class of this work is rip-rap or rocks thrown in piles, either confined in a crib or loosely against a pier or embankment. This is measured by the cubic yard, ton, cord of 128 cubic feet, or trois of 216 cubic feet depending upon where you are buying. Generally it has to be measured in piles, carts, or boats; it requires care and judgment to be fair to both parties. Next comes the same class of material carefully placed. The thickness is generally specified, care is taken that it is as thick as called for, and the area multiplied by this fixed depth gives the contents, usually by the cubic yard. Dry Rubble comes next in some form or other and usually consists of quite large field stones laid up by skilled masons according to the rules of the art. If a culvert, the wall sand covers are measured. The covers are specified a fixed thickness and to bear a fixed distance in the walls. The walls are also of fixed dimensions and care is taken that the work shall not be less than specified and measurements are made in these dimensions, so that the length is the only variable for the size of structure fixed upon. Next roughly dressed stone laid in mortar, dimensions are laid down and the work is measured to these dimensions. There may be several kinds of this masonry depending upon the kind of mortar used, usually measured by the cubic yard though for some work the perch of 24¾ cubic feet — one rod long, one foot high and one and one half feet wide, is used, generally called 25 cubic feet. Then the concretes, and these are of many varieties depending upon the proportions of sand to cement, the kind of cement and especially the purpose for which it is to be used This subject would require an evening by itself to do it justice One thing is safe to remember however, that the mortar in a given volume of concrete should exceed the voids in the stone or other material by about ten per cent. After concrete comes Second Class Masonry. This is well proportioned stone laid in cement mortars to a good bed and bond, only the courses are not necessarily of the same height In other words the builder is not compelled to get his stone all of one thickness, for the whole structure but may vary them to suit his quarry convenience. Last is Ashlar; this is of regular shaped stones having fixed dimensions and joints of any definite closeness from ¼" or less to ¾" laid in cement mortar and having the face either quarry faced or cut to any degree of fineness. The last two classes may be either by the cubic yard or they may go into all the details of stone cutting. This also would take quite a time to make a full description.

WOOD:— Logs by the thousand feet board measure generally procured and in place. The measuring of logs is one of the arts of trade. It would be well to have an understanding as to the scale to be used. One is to use the inch boards that are in the square which can be inscribed in the circle at the top end, that is the Ft. B M. in stick = $(d^2 \div 2 \times 12) \times l$ that is: length in feet by the square of the diameter at the top end in inches divided by 2 and 12. For the square of the diameter is twice the square of the side of the inscribed square; this divided by 12 —the number of square inches in a board 1 ft. wide and 1 inch thick—gives the required ft. b. m. per lineal foot. Another method of payment is by the ton of 40 cu. ft. In this case the solid contents of the log are taken as a truncated cone. The prismoidal formula is handy for this purpose using a table of circles for areas. They may be paid for by the lineal foot Logs are not used so much as sawn or hewn timber. This is usually measured by the ft. b. m., the ton, or cubic foot. Sometimes the prices are for the work in place with iron bolts included in the cost of the timbers, and sometimes the iron is paid for separate, by the pound; and again at a price per lineal foot for the material in the work with the iron separate. As long as the understanding is definite that is all that that is necessary. This class of work is for the foundation and protection work wharves etc. Bridge timbers, trestles etc. usually by the ft. b. m. Piles by the running foot or by the piece — *i. e.* stick - the driving may be by the pile or lineal foot driven, and the capping by the pile or cap, or this work may be done by the lineal foot of finished work.

Steel or iron structures by the pound or by lump sum for the completed structure. Ballast by the cubic yard under ties. Ties or sleepers by the piece, track laying by the mile, siding measured from head block to head block.

Rails by the gross ton of 2240 lbs. usually. The number of gross tons per mile is equal to the weight of a yard of rail by eleven and divided by seven, that is to say there are 88 tons of 56 lbs per yard rails in a mile. Fishplates and splicers, bolts, spikes and tie plates by the pound or 100 lbs. or cwt. Switches and fitings by the set, frogs the same. Unenumerated work at cost with a per centage added.

We now have a basis of payment upon which a contract can be made and usually tenders are called for and a copy of the specifications, plans and profiles are placed so that intending bidders can inspect them. They are generally explained by the engineer if needed, though it is important that only known facts are stated as, in the general legal idea, that the principal is responsible for the acts of his agent, any mis-statement by the engineer may result in a legal penalty by the Company which he represents. It is generally required of the intending contractor that he shall make a cash or equivalent deposit with his tender as an evidence of good faith and ability to do what he agrees to, though this is not always done. If the tenders are for a lump sum, the decision of award of contract is generally made by the Company itself, the engineer having previously given his estimate. If by the unit as previously described, the engineer has an approximate estimate of the quantities of each kind of work, which he expects to have done and to these quantities he applies the price per unit, as tendered, the sum of which quantities, expressed in money is the measure of the relative value of the several tenders

Here is where one not acquainted with the work may be misled by the unit prices. Where there are a number of different items one contractor may, for some reason or another be better fitted to do one kind of work than another and he knows just what he can do, and about what it will pay in the form of net profits per-centage. This may be quite a large part of the work in money value — while another part may be comparatively small in money value and he not be familiar with it if he is sure of his profit in the whole job he may fix his price on some items to be sure of this profit, and may tender give-away prices in some of the other work, [illegible] not care, or think advisable, to do certain work that has been called for, and put on such high prices that it will be avoided as much as possible. Thus I have seen tenders in which the price per cubic yard of rock was bid at one cent per cubic yard when it was so situated that it might cost him at least 125 times as much if not several times over, yet his tender was a good one when taken as a whole. Of course this is an extreme case and probably he had reason to know the quantity would be very small, but it shows that bids as published are very unsafe guides, unless one is familiar with all of the circumstances. I am also familiar with another case in which the engineer had specified a very difficult piece of work when a much simpler kind would have done just as well and better. The tender in this item was made 60 or 70 per cent. higher in order that an inducement might be presented, to cause a change to the more simple method, or, if it had been done, to protect the contractor from possible loss on uncertain difficult work.

We will now assume that the contract has been signed, and we are now ready to go to work and build the road. If we stop to consider just what this means from a mechanical point of view, we shall then know best how to use the means which are at our disposal to the best advantage.

A railway considered mechanically is an appliance by which men and property may be moved along its path, with the least expenditure of effort and greatest facility possible, consistant with the conditions by which it is surrounded.

The ideal and perfect theoretical road is straight and level,and that is the best road which comes the nearest to this ideal that its conditions will permit

Perhaps this it putting the case a little too strong, for it has been found impracticable to move trains of greater length than 75 cars, as has been found on some of the prairie roads. But grades consume fuel, and curves increase the wear in rails and rolling stock and are hard to maintain in uniform surface. Here is a case where we have to contend with natural laws and submit to the penalty of extra wear and expense in the use of our track. There is also another trouble, when we change direction by means of a curve. If our train has velocity, it will develope centrifugal force — but this force is an element of the velocity – if the velocity is varied the force is varied also. The only way in which the railway engineer can counteract this force is by placing the outer rail higher than the inner one. If the speed was constant this could be so adjusted that the force of gravitation would just balance the centrifugal force, but the speed is not constant and we can only fix upon a compromise inclination which shall prevent high speed trains aided by their wheel flanges from going over the outside rail and low speed ones from sliding too hard against the inner rail. When we have once fixed upon this inclination it is important that we keep it uniform; for the centrifugal force is uniform for a fixed speed, if the inclination varies, it causes this force to be irregularly resisted and causes a series of shocks to be imparted to both the rolling stock and the track with the penalty of extra and sometimes unexpected wear. A civil engineer of much experience told me of rails on one of the lines with which he was connected showing excessive wear and it was only when he found out by test that the inclination was not uniform that he could account for this wear.

Another trouble with a curve is that the axis of the truck, instead of being parallel with that of the car body must assume a position at right angles to a different radius from that to which the axis of car body is at right angles, that is to say, they change from parallel to an angle the one with the other. As the truck is relatively very short, at high speed on a curve of short radius, this change may take place almost instantly, that is to say, the change comes as a shock or blow which produces wear and injury in proportion to the square of the velocity. Fortunately this can be met by a spiral curve, that is to say by compounding the curve from the radius infinity of the tangent till it becomes that of the curve of location. This compound curve being extended over such a distance as will best suit the conditions of the particular road.

We see therefore that it is necessary that the track, which is the engineer's part to get in place, should be maintained in constant line and surface, to be economically operated. In order to maintain it in this condition it is desirable that we have uniform material. This we cannot get except it be brought from one place where the best can be found Therefore we form the grade low at first and support our track on ballast. But no material is the same when wet as when dry. Therefore we must keep it as dry as we can, and the real secret of good railroading is to keep an excess of water away from the ballast after the road is once ballasted.

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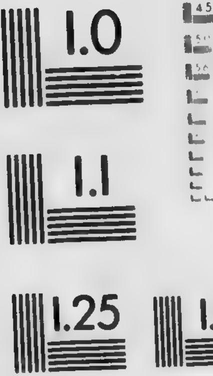

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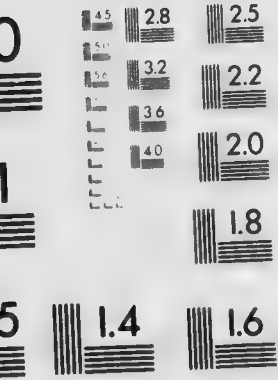

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